The Effect of Marketing Imperfection Variables on Production in the Context of Brazilian Agriculture

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Keywords: Stochastic Frontier, Endogeneity, Market Imperfections, Agricultural Census.

Abstract: In the context of the Brazilian agriculture it is of importance for policy makers the assessment of the effect on production of variables related to market imperfections. Market imperfection or asymmetry occurs when farmers are subjected to different market conditions depending on their size or their importance on overall state production. Relatively large rich farmers obtain lower input prices and may sell their production at lower prices making competition harder for small farmers. Market imperfections are typically associated with infrastructure, environment control requirements and the presence of technical assistance. In this article, at county level and using agricultural census data, we estimate the elasticities of these variables on production by maximum likelihood methods. We show that all these variables affect production significantly. Technological inputs dominate the production response, followed by labor and land. Environment control has a positive effect on production, as well as technical assistance. The logistics of production mostly affects technical efficiency. The proportion of forested areas has a negative elasticity. We also test technical assistance for endogeneity.

1 INTRODUCTION

The dataset of the Brazilian agricultural census of 2006 has been extensively studied, with primarily interest in topics related to production economy. A typical example of this literature is Helfand et al. (2015). An instance analyzing regional aspects of the 2006 census can be seen in Alves et al. (2017).

The Brazilian agricultural census of 2006 indicated a high concentration of production in the agricultural sector. See Alves et al. (2013) for details. In fact, the agriculture modernization in the recent past left out 3.9 million rural establishments, of a total of 4.4 million. Only five hundred thousand, 11.4% of the total, produced 87% of the total production value in 2006. These facts motivate studies identifying factors of importance for public policies leading to productive inclusion in agriculture in Brazil. Proper policies would increase the rural gross domestic product significantly and simultaneously reduce rural income concentration. Some studies in this topic are Alves et al. (2013), Ney and Hoffman (2008, 2009), Ferreira and Souza (2007) and Neder and Silva (2004).

Market imperfections are the main cause inhibiting the access of farmers to technology and, therefore, to productive inclusion. This concept is discussed in Alves and Souza (2015). Market imperfections are the result of asymmetry in credit for production, infrastructure, information availability, rural extension and technical assistance, among others.

Market imperfections are typically unfavorable to the small production. The lack of physical infrastructure and education make it difficult the rural extension to fulfill its role and, therefore, the proper access to technology. Another point to be emphasized is related to the imperfection of the production markets. Souza et al. (2017) highlight that small farmers sell their products at lower values and buy inputs at higher prices. The larger producers are able to negotiate better input and output prices and the existence of these different prices also characterizes a market imperfection. The unfavorable negotiation may lead to higher prices for the adoption of better technologies and, thus, lead to difficulties to achieve higher economic efficiency.

Souza, G. and Gomes, E.
The Effect of Marketing Imperfection Variables on Production in the Context of Brazilian Agriculture.
DOI: 10.5220/0006509300150020
In *Proceedings of the 7th International Conference on Operations Research and Enterprise Systems (ICORES 2018)*, pages 15-20
ISBN: 978-989-758-285-1

Our contribution to this literature is the identification, on a county basis, of a set of covariates representing proxies to infrastructure, environmental aspects and technical assistance, potentially related to market imperfections affecting production and the technical efficiency of production. The analysis is based on maximum likelihood estimation under endogeneity, assuming a stochastic frontier defined by a normal-half normal combination, where technical assistance is endogenous and infrastructure aspects affects the inefficiency component of the model.

2 DATA

The main data source for this paper is the Brazilian agricultural census of 2006 (IBGE, 2012a). We also used variables computed from the demographic census of 2010 and from other official sources of information. We follow the approach of Souza et al. (2013, 2017) in the definition of production and contextual variables.

Production (inputs and output) is defined using monetary values. The output variable is the value of production and the inputs are expenses on labor, land and technological inputs, which includes machinery, improvements in the farm, equipment rental, value of permanent crops, value of animals, value of forests in the establishment, value of seeds, value of salt and fodder, value of medication, fertilizers, manure, pesticides, expenses with fuel, electricity, storage, services provided, raw materials, incubation of eggs and other expenses. Value of permanent crops, forests, machinery, improvements on the farm, animals and equipment rental were depreciated at a rate of 6 percent a year (machines – 15 years, planted forests – 20 years, permanent cultures – 15 years, improvements – 50 years, animals – 5 years). Farm data from the agricultural census were aggregated to form totals for each county. A total of 4,965 counties (almost 90% of the total) provided valid data for our analysis.

The contextual variables we chose are a performance county index of social development, the proportion of farmers who received technical assistance, the proportion of non-degraded areas and the proportion of forested areas.

The index of social development reflects the level of well-being, favored by factors such as the availability of water and electric energy in the rural residences, level of education, health and poverty in the rural households. It was computed as a weighted average of normalized ranks of the following variables: education (illiteracy rate), poverty index, average gross per capita income of rural households, proportion of farms with access to electricity and water, index of basic education, index of performance of the public health system and vulnerability of children up to 5 years old. These indicators were obtained from the Brazilian demographic census 2010 (IBGE, 2012b), from the Brazilian agricultural census 2006 (IBGE, 2012a), and from the databases of the National Institute of Research and Educational Studies (INEP), referring to education in 2009 (INEP, 2012), and of the Ministry of Health 2011 data (Ministério da Saúde, 2011). The social score was computed using the ranks of these measurements, weighted by the relative multiple correlation coefficient. We see these contextual variables as proxies to market imperfections

3 METHODOLOGY

Our approach to assess production and efficiency of production follows along the lines of Karakaplan and Kutlu (2013) and Karakaplan (2017). The structural model for our application is defined by (1) for county *i*, where *techassist* is assumed endogenous and y_i is the log of gross income.

$$\begin{aligned}
& y_i = b_0 + b_1 \log(labor_i) + b_2 \log(land_i) + \\
& \quad b_3 \log(techinputs_i) + b_4 \log(forest_i) + \\
& \quad b_5 \log(ndareas_i) + b_6 \log(techassist_i) + \\
& \quad v_i - u_i \\
& v_i \sim N(0, \sigma^2) \\
& u_i \sim N(0, \sigma_{ui}^2) \\
& \sigma_{ui}^2 = \exp(b_7 + b_8 social_i) \\
& v_i, u_i \text{ independent}
\end{aligned} \quad (1)$$

Endogeneity in this context means correlation of the endogenous variable with v_i. This assumption invalidates the classic stochastic frontier analysis. A convenient approach is to use two stage least squares or general method of moments (GMM), as suggested in Amsler et al. (2016). Karakaplan and Kutlu (2013) suggest the use of instrumental variables in a context of maximum likelihood estimation, resembling classical frontier analysis. In our application we follow this approach and the instruments considered for *techassist* are the exogenous variables plus a demographic indicator.

The instrumental variable regression is presented in (2).

$$techassist_i = d_0 + d_1 \log(labor_i) + d_2 \log(land_i) + d_3 \log(techinputs_i) + d_4 \log(forest_i) + d_5 \log(ndareas_i) + d_6 demo_i + \varepsilon_i \quad (2)$$

We assume the variance-covariance matrix of the error term of this regression to be of the form $\sigma_\varepsilon^2 I$. Let ρ be the correlation between ε_i and v_i. Endogeneity means $\rho \neq 0$. We assume (3).

$$\begin{bmatrix} \tilde{\varepsilon}_i \\ v_i \end{bmatrix} = \begin{bmatrix} \varepsilon_i/\sigma_\varepsilon \\ v_i \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix}\right) \quad (3)$$

Using a Cholesky decomposition we may write (4), leading to the new frontier equation (5).

$$\begin{bmatrix} \tilde{\varepsilon}_i \\ v_i \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \rho\sigma & \sigma\sqrt{1-\rho^2} \end{bmatrix} \begin{bmatrix} \tilde{\varepsilon}_i \\ \tilde{w}_i \end{bmatrix} \quad (4)$$

$$\begin{aligned} y_i &= b_0 + b_1 \log(labor_i) + b_2 \log(land_i) + \\ &\quad b_3 \log(techinputs_i) + b_4 \log(forest_i) + \\ &\quad b_5 \log(ndareas_i) + b_6 \log(techassist_i) + \\ &\quad \eta\tilde{\varepsilon}_i + w_i - u_i \end{aligned} \quad (5)$$

$$w_i = \sigma\sqrt{1-\rho^2}\,\tilde{w}_i$$

$$\eta = \rho\sigma$$

The component $\eta\tilde{\varepsilon}_i$ is the correction term for bias. The test of $\eta = 0$ is an endogeneity test. The model is estimated by maximum likelihood. The likelihood function is given by (6), as stated in Karakaplan (2017).

$$\log L(\theta) = \sum_{i=1}^{n} \left\{ \frac{\ln(2/\pi) - \ln(\sigma_{Si}^2) - (e_i/\sigma_{Si}^2)}{2} + \ln \Phi\left(\frac{\lambda_i e_i}{\sigma_{Si}}\right) \right\} + \sum_{i=1}^{n} \left\{ \frac{\ln 2\pi - \ln \sigma_\varepsilon - \sum_{i=1}^{n} (\varepsilon_i^2/\sigma_\varepsilon^2)}{2} \right\} \quad (6)$$

In (6), $\lambda_i = \sigma_{ui}/\sigma$ and $\sigma_{Si}^2 = \sigma_{ui}^2 + \sigma^2$. e_i is defined as in (7).

$$e_i = y_i - \begin{pmatrix} b_0 + b_1 \log(labor_i) + b_2 \log(land_i) + \\ b_3 \log(techinputs_i) + b_4 \log(forest_i) + \\ b_5 \log(ndareas_i) + \\ b_6 \log(techassist_i) + \eta\tilde{\varepsilon}_i \end{pmatrix} \quad (7)$$

4 STATISTICAL RESULTS

The results of the maximum likelihood estimation described above applied to our dataset led to the statistical inference results reported in Table 1.

We see that the endogeneity effect is not statistically significant. Technological inputs dominate the production function, followed by labor and land. See Table 2 for the relative elasticity results, with the corresponding standard errors. This result has strong implications for technology diffusion in the Brazilian agriculture. Producers who are not able to use technological inputs will not be productive and will be very likely inefficient. This is a clear message for public policies related to agricultural extension. An effort must be made to reduce market imperfections to increase productive inclusion, particularly for small farmers. From Table 2 we see that the technology shows decreasing returns to scale, fact that allows net income maximization.

Technical assistance, non-degraded areas and proportion of forested areas are all statistically significant (Table 1). The former act favoring production and the latter has a negative effect. The direct implication is that caring for the environment will cost more for production in the short run. Here we see the importance of the rural extension and public policies, both envisaging adding value to forest preservation. As far as rural development indicators are concerned, we see environment as closely related to technology. The non endogeneity of technical assistance is an important fact, since it allows the use of this variable in regressions, as in Souza et al. (2013, 2017a).

Table 3 shows 5-number summaries for technical efficiency. Figure 1 shows the corresponding box plots for the efficiency measurements. Efficiency differs significantly by region. The social indicator affects positively technical efficiency, as reported in Table 1. Regions that are to benefit the most with improvements in the social indicators are the North and Northeast. This is clear from Figure 1, where efficiencies in the Northern and Northeastern regions are dominated by the corresponding measurements in the other regions. We notice that efficiency is a monotone increasing function of the social indicator.

Although technical assistance has a positive overall effect (Table 1), as already pointed out by Souza et al. (2017b), on a regional basis, technical assistance is not reaching properly the Northern and Northeastern regions. Issues of infrastructure and market imperfections are very likely affecting the majority of rural producers, inhibiting the proper use of technology. The fact observed in Souza et al (2017b) is that income concentration is highly correlated with efficiency in all regions, indicating that technology concentrates income in the rural Brazil.

Table 1: Maximum likelihood estimation results.

	Coefficient	Standard error	z	P>|z|	[95% Confidence interval]	
Frontier – *y*						
log(*labor*)	0,23115	0,011531	200,04	0,000	0,208536	0,253738
log(*land*)	0,09003	0,013968	60,45	0,000	0,062653	0,117406
log(*techinputs*)	0,45581	0,021104	210,60	0,000	0,414446	0,497173
forest	-0,12398	0,032878	-30,77	0,000	-0,188420	-0,059540
ndareas	0,25014	0,036281	60,89	0,000	0,179030	0,321249
techassist	0,56781	0,140459	40,04	0,000	0,292514	0,843105
constant	20,7368	0,104023	260,31	0,000	20,532930	20,940690
Instruments – *techassist*						
demographic	-0,12634	0,028992	-40,36	0,000	-0,18316	-0,069520
log(*labor*)	-0,02131	0,003139	-60,79	0,000	-0,027470	-0,015160
log(*land*)	0,00791	0,003929	20,01	0,044	0,000207	0,015606
log(*techinputs*)	0,07774	0,004742	160,39	0,000	0,068443	0,087031
forest	0,02043	0,009285	20,20	0,028	0,002227	0,038624
ndareas	0,08650	0,008944	90,67	0,000	0,068967	0,104026
social	0,65907	0,015642	420,14	0,000	0,628409	0,689723
constant	-0,44813	0,023053	-190,44	0,000	-0,493310	-0,402940
$\ln \sigma_u^2$						
social	-20,1779	0,737983	-20,95	0,003	-30,6243	-0,73147
constant	-20,4784	0,762352	-30,25	0,001	-30,9726	-0,98419
$\ln \sigma_w^2$						
constant	-0,9899	0,027306	-360,25	0	-10,0434	-0,93638

Endogeneity Test ($\eta = 0$)
Ho: Correction for endogeneity is not necessary.
Ha: There is endogeneity in the model and correction is needed.
χ^2 (1) = 1.75
Prob > χ^2 = 0.1858
Result: Cannot reject Ho at 10% level.

Table 2: Relative elasticities.

Item	Relative elasticity	Standard error
Labor	0.297	0.016
Land	0.116	0.018
Technology	0.587	0.022
Returns to Scale	0.777	0.014

Table 3: Technical efficiency – 5-number summary.

Region	Min	Q1	Median	Q3	Max
All	0,669	0,851	0,883	0,905	0,941
North	0,669	0,843	0,860	0,874	0,922
Northeast	0,679	0,828	0,845	0,864	0,934
Southeast	0,780	0,882	0,901	0,913	0,941
South	0,813	0,895	0,905	0,914	0,938
Center-west	0,795	0,872	0,886	0,897	0,927

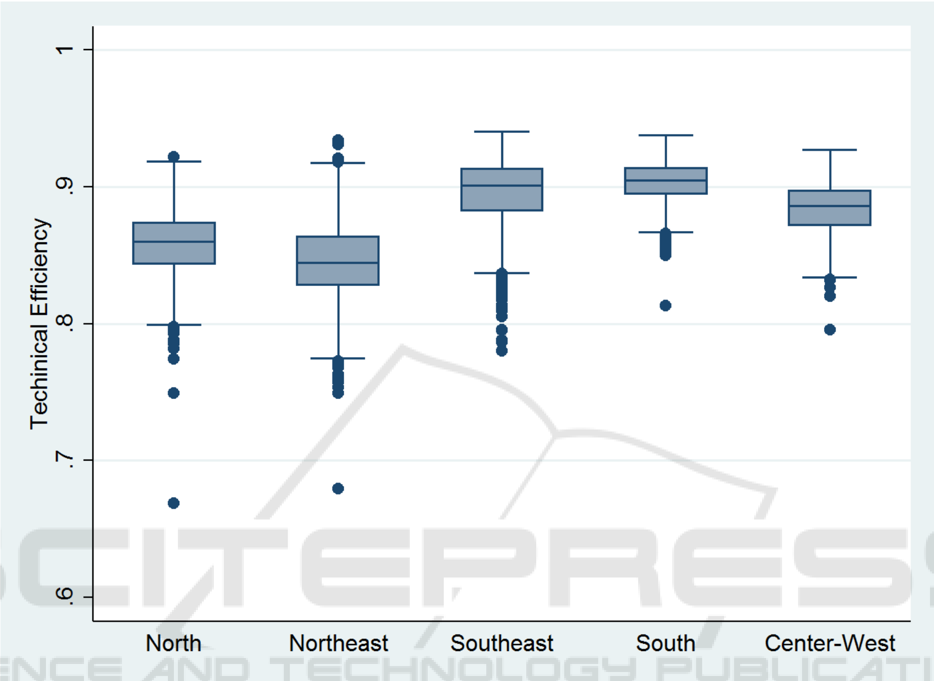

Figure 1: Box-plots of technical efficiency by region.

5 CONCLUDING REMARKS

We fitted a stochastic frontier under endogeneity to county data using the Brazilian agricultural census of 2006 – the last available. The objective of this study, besides assessing input elasticities, was to investigate effects of market imperfection variables on production. Market imperfections come from different realities in production experienced by small and large farmers. They relate to infrastructure, level of education, access to credit, implying in different input and output prices for small and large farmers. The presence of imbalances in market imperfection makes it harder for rural extension and technical assistance to promote productive inclusion.

For public policy decision making it is of importance the identification of component elasticities to guide rural governmental assistance. This is critical to reduce poverty in the fields and to increase production. We conclude that technology is the main input factor to increase income in rural Brazil. The social indicator is the key variable to reduce inefficiency. The indicator is relatively too low for the Northern and Northeastern regions. Values are less than half of the corresponding values of other regions. Public policies should be oriented to improve this indicator particularly in these regions. This means to improve infrastructure, education and health. These are overall issues to be handled both by the regional and national governments.

Technology is knowledge created by research and applied by producers through production systems. Mimicking other studies, it seems that only a few farmers are able to develop production systems that benefit from technology. Small scale agriculture needs to be reassessed and refocused, by means of public policies, to be able to access technology and become profitable.

Rural extension and technical assistance have a direct positive effect on income. Improvement of the social indicator will tend to facilitate the access of technical assistance creating, this way, a synergic positive effect on income.

Environment in our study was measured in two ways: non-degraded areas and the proportion of forested areas. Keeping non-degraded areas relates to technology and has a positive impact on production. On the other hand, keeping a relative large area of uncultivated land in the farm will have a negative effect on income. Extension and technical assistance may be the key factor to extract value from forests and properly preserve these areas.

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