

Full Research Article

## Technical efficiency in Brazilian citrus production

FELIPPE CLEMENTE\*, VIVIANI SILVA LÍRIO, MARÍLIA FERNANDA MACIEL GOMES

Federal University of Viçosa, Minas Gerais, Brazil

*Date of submission: November 17th, 2013*

**Abstract.** The purpose of this study was to analyze the technical efficiency of citrus producing properties in Sao Paulo state, in 2009 and 2010. For this, producers were interviewed; non-parametric data envelopment analysis approach was applied to calculate levels of technical efficiency, and an econometric approach was applied to establish technical efficiency determinants. The results showed that a great part of Sao Paulo citrus producing properties works inefficiently and the variables that mostly contribute to increase efficiency are “producer schooling “ and “experience as rural producer”.

**Keywords.** Technical efficiency, citrus sector, DEA.

**JEL Codes.** Q12, C25

---

### 1. Introduction

Orange culture is present in all Brazilian states in quite different production standards. At the same time, orange production is an activity concentrated in part of the country, as 96% of production comes from only six states, with distinction for Sao Paulo which is responsible for 78% of the production (Agrianual, 2010).

In the context of Brazilian agro-business the citrus sector stands out, comprising over 24 thousand rural properties and directly employing 11.2% of the agricultural workforce of Sao Paulo state and 2.2% of Brazil. In 2010, Brazil was the main orange producer in the world with 31% of production, followed by the United States and European Union with 16% and 11% respectively. In external sales the occupied post is equivalent: the country is the main exporter of concentrated frozen orange juice with nearly 80% of the international market. Added to this information is the fact that since 1994 orange juice exports have settled around 1.1 and 1.4 million tons, producing more than a billion dollars in foreign exchange (Neves, 2005).

Regarding the orange production in Sao Paulo state, despite its relative importance, it is noted that production is not uniformly distributed amongst citrus producers; there

---

\* Corresponding author: felippe.clemente@ufv.br.

is a discrepancy between the number of producers and the quantity produced. According to Clemente (2010), the orange production structure in the interior of São Paulo state is characterized by “many produce little” and “a few produce much”. Producers of up to 100 hectares correspond to 48% of the total number of producers, but they respond for only 17.5% of the production. In another extreme, producers with over 300 hectares correspond to only 17% of the total number of producers, but respond for 43.3% of the São Paulo production. From this information it is believed that there is room to investigate the existence of possible inefficiency in orange production in Sao Paulo.

In fact, the efficiency concept is relative and differs from efficacy and yield. Efficacy is linked only to what is produced, without considering the resources used for production. Yield is established by the ratio between what was produced and what was spent in production. Whereas efficiency compares what was produced, given the resources available, with what might have been produced with the same resources, so that, if the productive unit is very far from this parameter, it can be considered inefficient. There are two ways by which a technically inefficient unit can become efficient: the first one is by reducing inputs, maintaining constant production; the second is increasing production, maintaining constant inputs (Mello *et al.*, 2005).

In applied terms, efficiency analysis of productive units is important both for strategic aims (comparison between productive units), and for planning (evaluation of results of use of different combination factors) and for taking decision (such as improving current performance by analysis of distance between current production and potential production).

In this context, the purpose of the present study is to analyze the technical efficiency of citrus producing properties in Sao Paulo state, based on information corresponding to years 2009 and 2010, phase in which interviews were carried out with citrus producers so as to obtain information regarding orange production in each property.

For that, the present study is structured in four sections, besides this introduction. In section two, theoretical referential system of the study is presented and in section three is the analytical referential system. The main results obtained and the study conclusions are presented in sections five and six.

## **2. Evolution of Brazilian citrus sector**

The orange crop is widespread in Brazil, being cultivated in almost all states. At the same time, the orange is a spatially concentrated culture: around 96% of production comes from only six states, especially São Paulo, which accounts for about 78% of production (Agriannual, 2010). Next are Bahia, Sergipe, Minas Gerais, Paraná and Rio Grande do Sul, all with less than 7% of the national production (Table 1). The Southeast region has become the largest development center of the sector due to the exceptional fruit quality and favorable climate. In the 20s, the establishment of experimental stations in São Paulo and conducting research for citrus improvement enabled the provision of good quality fruit for the domestic market and export to Argentina, Uruguay, England and other European countries. According to Reis (2001), the citrus industry in Brazil took off from the stage called “conservative modernization” of agriculture, between the years 1965 to 1979, which had as its main features, among others, subsidized rural credit, export incentives

and tax exemptions. In addition, large fluctuations in the production of the United States, Brazil's main international competitor in the marketing of citrus, due to frequent frosts opened space for the placement of domestic production of fruit "in natura" and the frozen concentrated orange juice abroad which enabled the growth of acreage and processing industries orange (Maia, 1996). However, unlike other cultures strongly encouraged in this period, the citrus sector continued on a strong expansion also during the 1980s, when the international financial crisis caused depressive effects on the economy, reducing the supply of agricultural credit and reducing subsidies to the sector. In the 1990s, the growth process of the country continued to occur and currently Brazil is the main producer of Orange and also the main exporter of frozen concentrated orange (SLCC) juice, with about 80% market share.

**Table 1.** Brazilian citrus production – 2008.

States	Production	%
SP	353,228,235	78.4
BA	27,374,902	6.1
SE	18,923,284	4.2
MG	14,311,863	3.2
PR	12,681,373	2.8
RS	8,217,108	1.8
Brazil	450,850,956	100

The development of the Brazilian citrus industry began in the late 1950s. In 1959, it was installed the first juice concentrate factory in Brazil, Mining Beverage Company. In 1961, a company of Sao Paulo, Paulista Citrosuco, sent to the United States the first 1,000 tons of concentrated juice. However, the major impetus for the development of the Brazilian citrus industry was the frost that hit the orchards of Florida in 1962, reaching the destroy of 13 million adult trees. This frosting turned out to be a milestone for the Brazilian industry (Abecitrus, 2007). There was a shortage of raw material to supply the U.S. domestic market and European markets and the Brazil came to occupy these markets, accelerating the development of orange processing industry.

With the development of the processing industry of juice, there have been significant changes in the citrus sector. Firstly, the production structure has changed considerably. According Margarido (1998), industry growth stimulated the concentration of production in medium and large orange-producing properties, with a high rate of employment. Moreover, the consumption profile of the fruit changed with the possibility of processing and export. While in 1972 about 69% of Brazilian production was intended for the domestic market of fresh fruit and only 2% for export, at the end of the 80s, with the development of the industry, about 37% of the production was intended market "in natura" and more than 60% of Brazilian production was aimed at processing industry (Coelho, 1996). Currently, according to Neves (2005), 82% of fruit harvested are processed, leaving only 18% to the market in natura. Thus, the majority of Brazilian orange production is intended for the juice industry, which is concentrated in São Paulo. The citrus sector involves

more than 24,000 farms and directly employs about 11.2% of the agricultural labor force in the state of São Paulo and 2.2% in Brazil. Exports of orange juice remains, since 1994, between 1.1 and 1.4 million tons, generating more than \$ 1 billion of foreign exchange. (Neves, 2005).

### 3. Theoretical background

According to Lovell (1993), in micro-economic analyses the production function is normally represented as a relation between  $y$  the produced quantity of the good and a set of  $X_1, X_2, \dots, X_n$  which identify the quantities of several factors used, observing the most efficient production process. In other words, it is “a technical relation which associates to each endowment of production factors the maximum quantity of product obtained through the use of these factors” (Barbosa, 1985).

In this extent, the question of efficiency gains important outlines. For Sato (1975), the aggregation of production functions and their subsequent econometric estimate aiming at generating a macro production function, not taking into account differences in productive efficiency, yield biased results. Such results, when employed by agents responsible for the productive process, may compromise the efficient allocation of resources, which, most times, are scarce and expensive.

In other words, comparing different production units, errors may occur, should the analysis be based only on the mean production function estimate. This happens because there are differences in the use of production factors, which produce different levels of technical efficiency in production. Thus, in order to correctly appreciate the production function associated to a certain region or estate, it is necessary to eliminate the existing inefficiencies in each production unit, or to consider them appropriately in the intended analyses.

Given that, it is necessary to estimate a frontier production function that characterizes the best technology (best practice), from which comparisons can be made between production units in terms of production efficiency and structure of production technology.

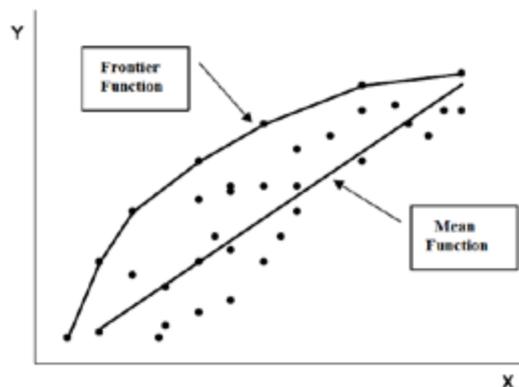
Figure 1 illustrates difference between a mean production function estimated by least squares and a frontier production function. It can be observed that in the mean function, while minimizing the deviation squares, there are points above and below the function. In the frontier function, all points are situated on or below it. Points on the frontier refer to efficient units. Similarly, points below the frontier present some type of inefficiency (Färe *et al.*, 1994).

Once this is done, it is possible to estimate the production function, which will best express the relations between inputs and product with no inefficiency.

## 4. Methodology

### 4.1 Data Envelopment Analysis

In a productive structure, the maximum quantities of products that can be obtained, given the inputs used, determine the production frontier (Lins and Meza, 2000). Orange production, as well as other agricultural activities, involves very variable production systems, making decision taking on the best allocation of resources a very complex matter.

**Figure 1.** Representation of production function

Data envelopment analysis (DEA) (Charnes *et al.*, 1978) use DMU's concept and is a non-parametric technique based on mathematical planning to analyze the relative efficiency of production units. In the literature related to DEA models, a production unit is considered a decision making unit (DMU), since these models provide measures to evaluate the relative efficiency of decision making units.

According to Ferreira (2005), the fundamental difference between the DEA approach and parametric analysis, such as the stochastic frontier, is in fact the first to be non-parametric estimating a deterministic frontier, and the second is parametric, based on stochastic function. A limitation to the use of the parametric approach to measure efficiency stems from the fact that it can present estimation problems, some of them are highlighted in Maietta (2002). Thus, the non-parametric approach that uses mathematical programming, like DEA, seems more appropriate. Another considerable advantage of DEA in relation to parameter estimation is the individual identification of each producer in the issue efficiency, which is possible through the efficiency scores generated by the operation of the model. These characteristics make the method a potentiality to explain with greater property and little interference from reviewers, the complexities inherent in real conditions (Ferreira, 2005).

Despite the advantages presented, this methodology also has disadvantages, among which stands out the sensitivity to the presence of outliers and the inclusion or exclusion of one or more units in the set of observations, the number of variables considered in the analysis, the impossibility of statistically test the results and also to disregard the presence of random factors and measurement errors, so that the whole distance to the border is considered due to inefficiency (Bonaccorsi and Daraio, 2004).

Alternatives to DEA methodologies were developed in order to advance in studies on efficiency. In this sense, Aigner, Lovell and Schmidt (1977) proposed a specific production function for "cross-section" data, in which deviations in relation to the production function could be due to productive inefficiency and random effects. This function is called stochastic production frontier (SFA).

The SFA model has advantages, with little sensitivity to the problems of measurement errors, the estimation of confidence intervals for the coefficients of efficiency to take a

chance on returns to scale and the major disadvantages such as the fact can suffer from the same problems of traditional regression analysis, the limitations related to the omission of variables, possible autocorrelation of errors, heteroscedasticity and endogeneity (Bonaccorsi and Daraio, 2004).

Thus, notes-that there is no consensus in the literature justifying the choice of the DEA or stochastic frontier, as both have advantages and disadvantages. The choice of DEA model to this work was due mainly to the size of the database analysis.

To incorporate the multi-product and multi-input production nature, Charnes *et al.* (1994) proposes the DEA technique for analysis of different units, regarding relative efficiency.

The distance<sup>1</sup> function is employed to incorporate the multi-product and multi-input nature in the productivity and efficiency analysis, without the necessity of specifying behavioral goals of decision makers.

According to Bravo-Ureta and Pinheiro (1993), the convenient form of describing the multi-product characteristic of production is by production technology, defined by set  $S$ , represented in equation (1):

$$S=\{(x, y) : x \text{ can produce } y\} \quad (1)$$

which is defined by the set of all input and product vectors  $(x, y)$  so that  $x$  can produce  $y$  in which  $x$  is a non-negative input vector ( $k \times 1$ ) and  $y$  a non-negative product vector ( $m \times 1$ )

The set of production technologies can equivalently be defined by the set of production possibilities  $P(x)$ , which represents the set of all product vectors  $y$ , that can be produced by the input vector  $x$  in other words,

$$Px=\{y : x \text{ can produce } y\} \quad (2)$$

The distance function with product orientation, according to Coelli *et al.* (2005), can be defined by the set of products  $P(x)$  as

$$d_0(x, y) = \min \varnothing : \frac{y}{\varnothing} \in P(x) \quad (3)$$

$$d_0(x, y) = \left( \max \{ \varnothing : (\varnothing y) \in P(x) \} \right)^{-1} \quad (4)$$

in which,  $\varnothing$  in expression (3) is: the inverse of the factor by which the production of all output quantities could be increased while still remaining within the feasible production possibility set for the given input level (Coelli, Prasada Rao and Battese, 1998).

The distance function  $d_0(x, y)$  might have values lower or equal to 1, if the product vector  $y$  is an element of the set of possibility of production  $P(x)$ ; if it is equal to 1,  $(x, y)$  it will be on the technological frontier; thus, production will be technically efficient.

---

<sup>1</sup> It can be defined as input orientation and product orientation. Input orientation characterizes production technology by proportional minimization (contraction) of input vector, given a product vector. Product orientation characterizes production technology by proportional maximization of product vector, given an input vector.

The product-oriented DEA model with assumption of non-constant returns to scale tries to maximize the proportional increase at the product level, maintaining the quantity of inputs fixed. In accordance with Charnes *et al.* (1994), it can be algebraically represented as:

$$d_0(x, y)^{-1} = MAX_{\theta, \lambda, S^+, S^-} \phi \tag{5}$$

subject to:

$$\phi y_i - Y\lambda + S^+ = 0$$

$$-x_i + X\lambda + S^- = 0$$

$$N1'\lambda \leq 1$$

$$\lambda \geq 0$$

$$S^+ \geq 0$$

$$S^- \geq 0$$

in which  $Y_i$  is a vector ( $m \times 1$ ) of product quantities of the  $i$ -th DMU;  $x_i$  is a vector ( $k \times 1$ ) of input quantities of the  $i$ -th DMU;  $Y$  is a matrix ( $n \times m$ ) of nDMUs products;  $X$  is a matrix ( $n \times k$ ) of n DMUs inputs;  $\lambda$  is a weight vector ( $n \times 1$ );  $N1$  is a vector ( $n \times 1$ ) of number ones;  $S^+$  is a vector of floats related to products;  $S^-$  is a vector of floats related to inputs; and  $\phi$  is a scalar that has vectors equal to or higher than 1 and indicates DMUs efficiency score, in other words, a value equal to 1 indicates technical efficiency of the  $i$ -th DMU, in relation to the rest, while a value higher than 1 shows the presence of relative technical inefficiency. The problem presented in (5) is solved  $n$  times – once for each DMU, and, as a result, presents values of  $\phi$  and  $\lambda$ ,  $\phi$  the DMU efficiency score under analysis  $\lambda$  supplies the peers (efficient DMUs that serve as reference for the  $i$ -th inefficient DMU).

#### 4.2 The second stage

Although the use of Tobit models as “second stage”, to explain efficiency indices from DEA estimation of frontiers, has gained popularity in the 1990s and 2000, most recently McDonald (2009) showed that its use may be inappropriate, and that, in such applications, the estimator Maximum Likelihood (ML) is generally inconsistent, unlike the ordinary least squares estimator (OLS). As a consequence, it was estimated a regression using the method OLS.

At this point, one should try to concentrate on information referring to the properties characteristics (size and number of employees) and producer characteristics (age, schooling and experience as producer). It is expected that these variables positively impact on the fact of properties being efficient. Therefore the following equation was estimated, based on primary data obtained with a sample of citrus producers in Sao Paulo state:

$$Y_i = \beta_1 + \beta_2 I_i + \beta_3 E_i + \beta_4 Te_i + \beta_5 T_i + \beta_6 Nf_i + \varepsilon_i \tag{6}$$

in which:

$Y_i$  = efficiency scores obtained by Data envelopment Analysis. Consequently, each DMU has a positive efficiency coefficient, limited to the interval 0 to 1;

$I_i$  = producer age (in years);  
 $E_i$  = producer schooling (in years);  
 $Te_i$  = as rural producer (in years);  
 $T_i$  = property size (in hectares);  
 $Nf_i$  = number of employees in properties;  
 $\varepsilon_i$  = term.

The equation estimate (6) allows inferences to be made for the whole population without quality loss.

It is expected that all of these variables impacting positively on the efficiency of the property. Age and time as farmer demonstrate the skill from the branch of citrus. The education variable indicates the level of expertise of the grower and the variable size of the transformed property in the production of oranges implemented.

### 4.3 Study area

In order to investigate the level of production of the orange growers and the quantity of inputs used, interviews with orange producers of São Paulo were previously selected for application of a structured questionnaire were conducted from December 2009 to February, 2010. Growers of eleven cities in the state of São Paulo, a region that has the largest orange production in the country were interviewed. The State of São Paulo had, in 2006, approximately 6300 active growers, concentrating 81% of the national production of oranges. Neves (2005) shows that citrus regions in São Paulo are divided into North and Northeast, Central, South and New South (Figure 2). The first comprises the region Trough and Barretos, São José do Rio Preto and Votuporanga and Catanduva region, accounting for 45% of production in the state. Second, participating region of Araraquara and Matão, Itápolis and Taquaritinga, representing 30% of production. In the South, part of the region of Limeira, Avare/Botucatu and Itapetininga. Have the New South comprises of Bauru, Itapetininga. These last two regions concentrate 25% of production (Tavares, 2006).

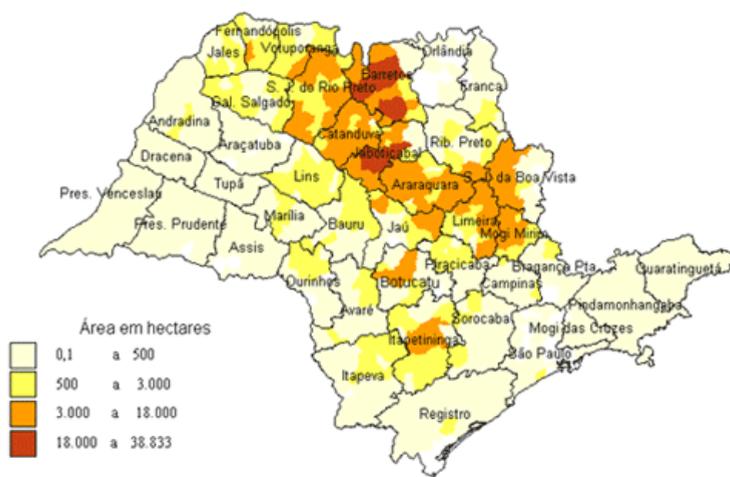
When the sample structure, aimed to select the regions where most growers are concentrated orange production in the state of São Paulo. The calculation of sample<sup>2</sup> size, with a confidence interval and tolerance of sampling error of 10%, resulted in 67 questionnaires.

For stratification of the sample, the participation of the regions in orange production in the state of São Paulo and then the production of the main regions in 2003 were used. Thus, we selected 30 questionnaires for the North and Northeast, 20 questionnaires for the Central region and 17 questionnaires to the South/New South. Because regions of Barretos, Catanduva and Sao Jose do Rio Preto is located in the North and Northeast, 17 questionnaires for the region of Barretos, 6 to 7 and Catanduva region to the region of São José do Rio Preto were applied. For the center, the 20 questionnaires were administered in the Araraquara region and for South/South New 10 questionnaires were administered in the region of Limeira, in the region of Jau 4 and 3 in the region of Bauru.

---

<sup>2</sup> Sample Size:  $n = \frac{Z^2 \cdot p \cdot q \cdot N}{[d^2 \cdot (N - 1) + Z^2 \cdot p \cdot q]}$  (Greene, 1993).

Figure 2. São Paulo regions.



#### 4.4 Source of data

The mean capital cost of properties in the interior of Sao Paulo State and the mean price of orange sold for industry were collected at the Institute of Agricultural Economy (IEA).

Aiming at investigating the characteristics of farmers and properties, an exploratory survey was carried out with 67 orange producers in eleven cities of Sao Paulo State in 2010.

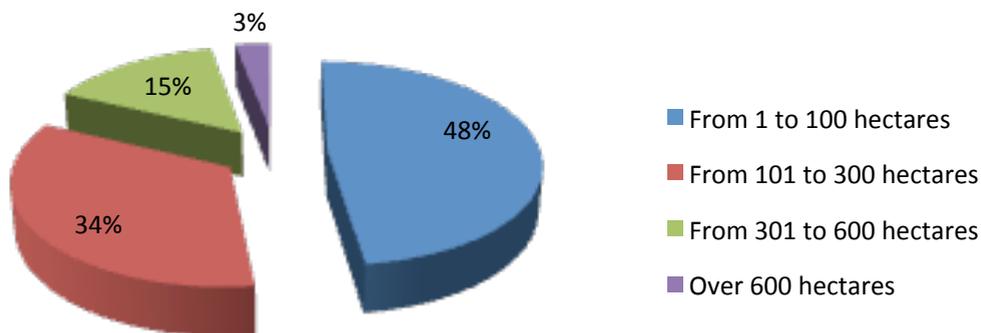
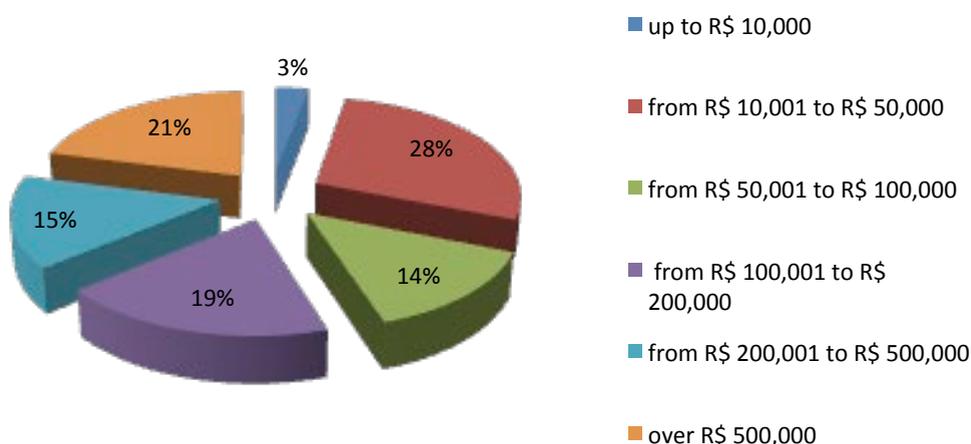
## 5. Results and discussion

### 5.1 Descriptive characteristics of sample

Structured questionnaires were applied to 67 orange producers in Sao Paulo state. The questionnaires aimed at investigating the characteristics of citrus producers and at collecting information about the property, such as size and number of employees.

Among the main characteristics, it was noticed that, in total, 34% of interviewed producers were aged between 23 and 50 years and 66% were over 50 years, which indicates the prevalence of older producers. In addition, it was observed that 33% of producers had studied up to 5 years and 51% had studied over 10 years. Regarding the experience as rural producer, the results show that 26% of producers were up to 20 years in the activity, 24% were in activity between 20 and 30 years and 50% have been producing over 30 years, showing the prevalence of citrus producers with a wide experience in the orange production.

From the analysis of property size (Figure 3), presence of “small“ and “average size“ properties stand up (up to 100 hectares), with 48%. For 81% of producers, the main source of income is agriculture and 55% obtain an annual gross income of over R\$ 100.000 with orange (Figure 4).

**Figure 3.** Property size.**Figure 4.** Annual gross income with orange.

As for the labor profile, it is noticed that 84% of properties have contracted labor and 16% count exclusively on family labor. Though the use of family labor is a characteristic of small properties, in this type of property the use of constant and paid labor has been found.

Regarding the number of constant employees, it was verified that the average of workers hired per property is approximately 6. However, there is a large disparity of labor between farms, since there are properties with up to 75 employees and properties with none. This is also shown by the high standard deviation value (11.75).

In summary, the results show differences in the productive characteristics of citrus properties in Sao Paulo state, particularly regarding schooling, gross income and experience as rural producer. These divergences may imply in certain orange production inefficiency in the region.

### 5.2 Analysis of technical efficiency

Technical efficiency compares what was produced, given the available resources, with what might have been produced with the same resources. Therefore, data envelopment analysis was used to verify the orange production efficiency in properties.

The variables employed in the efficiency model for sample as a whole, along with descriptive statistics are presented in Table 2.

**Table 2.** Descriptive statistics of variables employed in producer efficiency model, 2010.

Variable	Mean	Standard deviation	Maximum	Minimum
Orange production (40.8kg box)	34,920.59	39,444.87	136,263.00	738.37
Property size (in ha)	190.66	287.95	2,100.00	12.00
Number of employees	6.13	11.75	75.00	0.00
Capital cost (in R\$)	714,063.98	1,049,592.85	7,578,522.00	46,695.12
Producer age (in years)	55.21	13.11	79.00	23.00
Producer Schooling (in years)	9.93	5.43	17.00	1.00
Experience as producer (in years)	31.52	14.29	63.00	5.00

These variables reflect property characteristics (production, size, employees and capital cost) and producer characteristics (age, schooling and experience as producer). A relative difference in magnitude is evident in units that constitute the sample, particularly the high standard deviation resulting from relative dispersal of data around the mean, which declines central tendency inferences.

Table 3 shows statistical summary of technical efficiency calculation of units that constitute the sample. By the technical efficiency score means, it is possible to visualize the efficiency level in properties. Individualized scores allow more specific notes on each productive unit, indicating inefficiency in resources, as well as pointing to DMUs that serve as model. This observation is important to analyze the real situation of each property in detriment to group performance.

**Table 3.** Technical efficiency scores of citrus properties.

Variables	Efficient Units	Mean	Standard Deviation	Maximum	Minimum
Technical Efficiency	13.43%	0.79	0.21	1.00	0.25

The results demonstrate that citrus properties of Sao Paulo present significant technical inefficiency level.

The technical efficiency mean was 0.79, which suggests the possibility of production increase, considering the same proportion of inputs currently used, taking as reference the product-oriented model. While analyzing the producing regions of Sao Paulo State,

it can be observed that 67% of efficient properties are in the north and northeast of the state. This occurs due to the fact that these regions are the oldest in orange production in the country, which enabled producers to gain greater knowledge on the best combination of inputs. Regarding the most inefficient properties, 71.4% are located in the south and southeast regions of the state.

To compare the inefficiency level of productive units based on the technical efficiency mean score, an indicator was created and defined by Ferrier and Porter (1991), which follows:

$$\left( \frac{1}{score} - 1 \right) \times 100 \quad (14)$$

Thus, as this analysis is output-oriented, on average inefficient firms could produce 26.6% more output, given their inputs.

Aiming at verifying the efficiency determinants in citrus producing properties in Sao Paulo State, the OLS econometric model was used. The results of the model can be observed in Table 4. For analyze the possible correlation between “producer age” and “experience as rural producer”, we made other estimations in II and III.

**Table 4.** Factors associated to technical efficiency in citrus producing properties in Sao Paulo state – OLS model.

Variable	I	II	III
Property size	0.00028 <sup>NS</sup>	0.00037 <sup>NS</sup>	0.00017 <sup>NS</sup>
Number of employees	-0.010 <sup>NS</sup>	-0.0121 <sup>**</sup>	-0.0076 <sup>NS</sup>
Producer age	0.0063 <sup>NS</sup>	0.0099 <sup>**</sup>	-
Producer schooling	0.0145 <sup>**</sup>	0.0128 <sup>*</sup>	0.0136 <sup>*</sup>
Experience as rural producer	0.0048 <sup>NS</sup>	-	0.0087 <sup>***</sup>
Constant	1.391 <sup>***</sup>	1.422 <sup>***</sup>	1.148 <sup>***</sup>
R <sup>2</sup>	22.85	20.50	19.46

\* 10% of significance; \*\* 5% of significance; \*\*\* 1% of significance <sup>NS</sup> no significance.

We could observe in estimation I that only the variable “producer schooling” is significant at 5%. To the estimation III the variable “experience as rural producer” is a positive and highly significant determinant of efficiency, however the impact of “producer schooling” on technical efficiency is much stronger.

## 6. Conclusion

This study analyzed the efficiency of citrus producing properties in Sao Paulo State from 2009 to 2010, using the non-parametric data envelopment analysis approach to calculate technical efficiency levels. In addition, the OLS econometric model was used to find the technical efficiency determinants of citrus producers.

The results confirmed the hypothesis that citrus producing properties are inefficient. In other words, given that we have an output-orientation in this analysis, the farmers do not obtain the maximum output from their resources. The reduction of these inefficiencies could increase the production in the entire sector. The variables that mostly contribute to increase efficiency are “producer schooling” and “experience as rural producer”.

## References

- Aigner, D., Lovell, K. and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6(1): 21-37.
- Abecitrus (2007). Associação brasileira dos exportadores de cítricos. Informativo Abecitrus. Ribeirão Preto.
- Agrianual 2010. (2010). Anuário Estatístico da Agricultura Brasileira. São Paulo: Argos, Inc.
- Bonaccorsi, A. and Daraio, C. (2004). Econometric approaches to the analysis of productivity of R&D systems. Production functions and production frontiers. In: Moed, Glanzel, Shmoch (eds.), *Handbook on Quantitative Science and Technology Research*, Kluwer Academic Press.
- Bravo-Ureta, B.E. and Pinheiro, A.E. (1993). Efficiency analysis of developing country agriculture: a review of the frontier function literature, *Agricultural and Research Economic Review* 22: 88-101.
- Clemente, F. (2010). Viabilidade de Implantação de Contratos Futuros de Suco de Laranja Concentrado Congelado no Brasil. Monograph, Department of Rural Economics, Federal University of Viçosa, Viçosa, MG, Brazil.
- Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research* 2: 429-444.
- Charnes, A., Cooper, W. W., Lewin, A. Y. and Seiford, L. M. (1994). Data envelopment analysis: theory, methodology and application. Dordrecht: Kluwer Academic.
- Coelho, F.C. (1996). Análise do Mecanismo de Transmissão de Preços de Laranja e Soja Entre os Mercados Externo e Interno. Msc dissertation, Department of Rural Economics, Federal University of Viçosa, Viçosa, MG, Brazil.
- Coelli, T., O'Donnell, C.J. and Battese, G.E. (2005). An introduction to efficiency and productivity analysis. Springer.
- Ferreira, M.A.M. (2005). Eficiência técnica e de escala de cooperativas e sociedade de capital na indústria de laticínios do Brasil. PhD dissertation, Department of Rural Economics, Federal University of Viçosa, Viçosa, MG, Brazil.
- Gomes, A.P. and Baptista, A.J.M. S. (2009). Função de produção de fronteira e tomada de decisão na agropecuária. SOBER(2009), Belo Horizonte.
- Lins, M.P.E. and Meza, L.A. (2000). Análise envoltória de dados a perspectiva de integração no ambiente de apoio à decisão. Rio de Janeiro: COPPE/UFRJ, Inc.
- Lovell, C.A.K. (1993). Production frontiers and productive efficiency. In: Fried H., Lovell, C.A.K., Schmidt, S. (eds), *The measurement of productive efficiency: techniques and applications*. London: Oxford University Press.
- Maia, M.L. (1996). Citricultura paulista: evolução, estrutura e acordo de preços. São Paulo: IEA, Inc.

- Maietta, O.W. (2002). The effect of the normalisation of the shadow price vector on the cost function estimation, *Economics Letters* 77(3): 381-385.
- Margarido, M.A. (1998). Transmissão de preços internacionais de suco de laranja para preços ao nível de produtor de laranja no estado de São Paulo. São Paulo: IEA, Inc.
- Mello, J.C.B.S., Meza, L.A., Gomes, E.G. and Neto, L.B. (2005). Curso de análise de envoltória de dados. SBPO(2005), Gramado, RS.
- McDonald, J. (2009). Using least squares and tobit in second stage DEA efficiency analyses. *European Journal of Operational Research* 197: 792-798.
- Neves, M.F. (2005). Estratégias para a laranja no Brasil. São Paulo: Atlas S.A., Inc.
- Reis, B.S., Lirio, V.S. (2001). Negociações internacionais e propriedade intelectual no agronegócio. UFV: DER, Inc.
- Sato, K. (1975). Production functions and aggregation. Amsterdam: North-Holland publishing company.
- Tavares, M.F.F. (2006). O mercado futuro de suco de laranja concentrado e congelado: um enfoque analítico. PhD dissertation, Department of Economics, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil.