Economic Efficiency of Agricultural Production In Brazil[1]

José R. Vicente[2]

Abstract - This study measures levels of technical, allocative and economic efficiency in agricultural crop production for Brazil in 1995. A nonparametric frontier model (DEA) under constant returns to scale was used. On average, the results suggest that the sector suffers from moderate technical inefficiency and from strong allocative inefficiency. If full technical efficiency were achieved, the crop production would increase by more than 30% over that obtained in 1995. Land and labor were overutilized, while fertilizers and pesticides were underutilized. Climate, soil conditions and irrigation use affected technical efficiency levels, and education in rural areas helped explain the extent of allocative efficiency. The state of São Paulo State was the only production unit in Brazil operating in full efficiency in 1995.

Key Words – agricultural production, nonparametric frontier, economic efficiency, technical efficiency, allocative efficiency.

Jel Classification: Q12 e O30

---

[1]This study is part of wider research project that benefited from financial support from the State of São Paulo Research Foundation (FAPESP). I would like to thank Stephen A. Vosti (UC-Davis) for his very helpful comments and suggestions, and two anonymous referees. The usual disclaimer applies.
[2]Doctor in Economics, Research Fellow, Institute for Agricultural Economics (IEA), Av. Miguel Stéfano, 3900, Cep: 04301-903 - São Paulo, SP, Brazil.
E-mail: jrvicente@iea.sp.gov.br..

Resumo – *Este estudo mensurou os níveis de eficiências técnica, alocativa e econômica na produção agrícola, setor de lavouras, do Brasil em 1995. Um modelo de fronteira não-paramétrica (DEA) sob retornos constantes à escala foi utilizado. Os resultados mostraram, em média, a existência de ineficiência técnica moderada e de ineficiência alocativa forte. Sob eficiência técnica plena, a produção do setor de lavouras seria mais de 30% superior à obtida em 1995. Foi constatada sobreutilização de terra e trabalho e subutilização de fertilizantes e defensivos. As condições de clima e solo e o uso de irrigação condicionaram os níveis de eficiência técnica, e a escolaridade nas áreas rurais explicou o grau de eficiência alocativa. O Estado de São Paulo era a única unidade produtiva operando com eficiência econômica plena em 1995.*

Palavras-chave*: produção agrícola, fronteira não-paramétrica, eficiência econômica, eficiência técnica, eficiência alocativa.*

1 - Introduction

Over the period 1970-95, total factor productivity (TFP) of Brazilian crop production nearly doubled, stimulated by productivity growth of the two indispensable factors of production (Schumpeter, 1982) - land and labor - whose productivity increased 140%.

Although the Center-West region registered the largest rates of growth of TFP (over 161% during that period), the Southeast region always benefited from the largest productivity indices and these results were primarily attributable to the performance of agriculture in the state of São Paulo, which, in 1995, registered TFP index that were 2,3 times higher than the national average. On the other hand, the TFP indices in the North and Northeast regions were less than half of the national average in 1995.

Besides the regional diversity of growth rates of TFP, there was considerable nonuniformity in the evolution of prices paid and received by farmers, and consequently in the purchasing price parity indices across the Brazilian the federal units (UFs): the terms of trade in factor inputs in agriculture turns sharply against producers in the North and Northeast regions (Vicente et al., 2001c).

The decomposition of TFP shows that productivity increments in the more-developed agriculture Southeast and South regions were due mainly to technological progress, while increases of technical efficiency were more important in other areas; the North and the Northeast regions actually regressed technologically (Vicente, 2003).

Analysis of economic efficiency complements TFP studies by providing performance measures for evaluating production activities (Lovell, 1993) and by helping to identify the determinants of inefficiency, all of which are useful in guiding extension activities, research and technical support (Tupy et al, 2003). In the context of the national agricultural production, studies of economic efficiency can also shed light on the speed and geographic spread of agricultural modernization and productivity growth. For example, efficiency analysis can tell us if UFs with the largest TFP indices are also the most efficient, or, if temporary disequilibria caused by the adoption of new technologies (Schultz, 1975) has influenced the efficiency levels, or, if areas of low-productivity agriculture produce efficiently given factor endowments and relative prices (Schultz, 1965).

This study addresses these issues by estimating the economic efficiency of the Brazilian crop production at the UF level using data of the most recent Agricultural Census. In addition, the paper estimates production possibility frontiers for annual crops, and using this frontier measures the underutilization and overutilization of production factors, and via regression analysis identifies factors influencing production efficiency.

2 - Methodology

Firms produce an output y, sold at a price p>0, using a vector of n inputs $x=(x_1, ..., x_n)í$, available at prices $w=(w_1, ..., w_n)í>0$. The efficient transformation of inputs into output can be characterized by the production function $f(x)$ that represents the maximum output attainable from several input vectors. Another representation of efficient production technology can be the cost function $c(y,w)=min_x\{wíx \mid f(x)\geq y, x\geq 0\}$, that shows the necessary minimum expenditure for the production of y, given input prices w. A third representation is given by the profit function, $\pi(p,w)=max_{y,x}\{py\text{-}w\'{\imath}x \mid f(x) \geq y,\ x\geq 0,\ y\geq 0\}$, that identifies combination of inputs that maximize profit, given output and input prices. In the econometric literature, $f(x)$, $c(y,w)$ e $\pi(p,w)$ are considered typical frontiers, since they characterize optimizing behavior of an efficient producer, and establish the possible limits of their dependent variables (Førsund et al., 1980).

A production plan (y^o, x^o) is defined as technically efficient if $y^o=f(x^o)$, and as technically inefficient if $y^o<f(x^o)$; $y^o>f(x^o)$ is assumed to be impossible. One measure of the technical efficiency of this plan can be represented by $0 \leq y^o/f(x^o) \leq 1$. The technical inefficiency is due to the excessive input usage, which is costly, and so, $w\'{\imath}x^o \geq c(y^o, w)$; since cost was not minimized, the profit was not maximized, $(py^o\text{-}w\'{\imath}x^o) \leq \pi(p,w)$. The inefficiency can also be allocative, originating from the use of inputs in inadequate proportions, and generate higher costs and lower profits[3].

Farrel (1957), proposed a deterministic nonparametric frontier method[4] to estimate production functions and to measure technical and allocative efficiency[5]. Consider a firm producing output y using the inputs x_1 and x_2, and assume that the production function (frontier) is $y=f\ (x_1,x_2)$, under constant returns to scale it may be written $1=f\ (x_1,x_2)$, i.e., the technological frontier can be represented by a unit isoquant (figure 1)[6].

[3] The combination of technical and allocative efficiencies, although necessary, is not sufficient for the profit maximization, because the firm could still be scale inefficient, or, $p \neq c_y(y^o,w)$ (Forsund et al., 1980).
[4] For other methods of production frontier estimation, see Vicente (2002).
[5] Naturally, it can be argued that economic agents' decisions are simultaneous; therefore, decisions that affect allocative efficiency can affect technical efficiency, and vice-versa. Farrell (1957) attempted to disaggregate those joint decisions and measure their independent effects empirically (Kopp, 1981).
[6] The isoquant UU' (figure 1) is not observable and must be estimated from the sample data, including data points 'within' the production frontier, as represented by the point A.

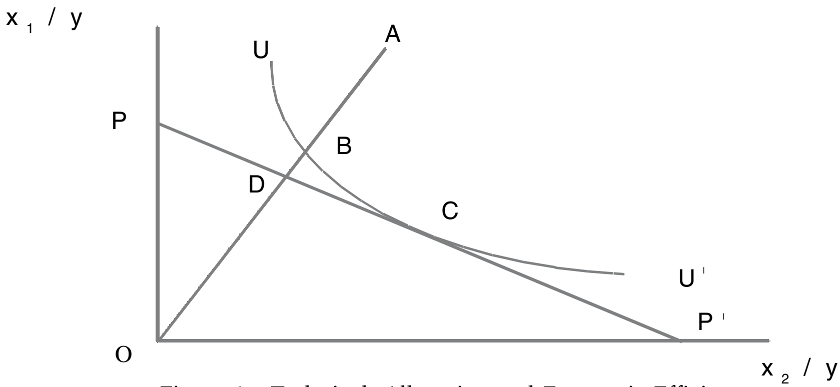

Figure 1 - Technical, Allocative and Economic Efficiency.
Source: Førsund et al. (1980).

If the point A, that by definition cannot lie below the curve UU', represents the production of the output y^0 using x_1^0 and x_2^0, then the ratio OB/OA - the ratio of inputs needed to produce y^0 to the inputs actually used to produce y^0 - measures technical inefficiency. The isoquant UU' characterizes the most efficient production as regards input use, and the deviations from it were considered by Farrell (1957) to be measures of the technical inefficiency of firms.

If the line PP' represents relative input prices, the ratio OD/OB measures allocative inefficiency, since the cost of point D is the same as that of the allocatively efficient point C, and is less than that of the technically efficient but allocative inefficiency point B. A measure of total efficiency (or economic efficiency) is provided by the ratio OD/OA (Førsund et al., 1980).

2.1 Data Envelopment Analysis (DEA)

DEA is method of constructing production frontiers without specifying production technology proposed by Charnes, Cooper and Rhodes (1978). The efficiency of a "decision making unit" (DMUs) is measured relative to all other units, with the simple restriction that all of them are on or below the efficient frontier (Seiford and Thrall, 1990).

More specifically, it is a linear programming methodology that uses data on outputs and inputs to construct complete linear production surfaces. The frontier surface is obtained by series of linear programming problems, one for each observation (DMU) in the sample[7] (Rao and Coelli, 1999). The measure of the inefficiency of each DMU is given by the distance between each point and the production frontier. In the present study, an input-oriented DEA was used to define the frontier based on the maximum possible proportional reduction in input usage, holding output levels constant for each observation.

Using the duality theorem, the mathematical programming problem under constant returns to scale can be represented by (Coelli, 1996):

$$\min_{\theta,\lambda} \theta \qquad (1)$$

subject to:

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0,$$

where $\theta \leq 1$ is a scalar representing the degree of technical efficiency (ET) of the i-th DMU[8], and λ is a vector (Nx1) of constants[9]. That linear programming problem must be solved N times, once for each observation in the sample.

If inputs prices are available, it is possible to measure technical and allocative efficiency by solving the following cost minimization DEA model (Coelli, 1996):

$$\min_{\lambda,x_i} w_i' x_i^*, \qquad (2)$$

subject to:

$$-y_i + Y\lambda \geq 0,$$
$$x^*_i - X\lambda \geq 0,$$
$$\lambda \geq 0,$$

where w_i is an input price vector for the i-th DMU, and x_i^* it is the cost-minimizing vector of input quantities for the *i-th* DMU given input prices (w_i) and output levels (y_i).

---

7 In this case, the Units of the Federation (UFs).

8 A value of $\theta = 1$ indicates a point on the frontier, in other words, an efficient DMU according to Farrell's (1957) definition.

9 In the case of an efficient DMU, all the values of λ will be equal to zero; for the inefficient DMUs, the values of λ are the weights used in the combination of efficient DMUs that project each inefficient DMU onto the frontier (Tupy et al., 2003).

The economic efficiency (or total efficiency, or cost efficiency) of the *i-th* DMU can be calculated by (Coelli, 1996):

$$EE_i = w_i^{¥} x_i^{*} / w_i^{¥} x_i \qquad (3)$$

that is, the ratio of minimum cost to the observed cost.

Allocative efficiency (EA) is obtained residually:

$$EA_i = EE_i / ET_i \qquad (4)$$

Indicators of underutilization and overutilization of inputs flow directly from the previous efficiencies calculations. Production potential (the frontier), given input levels for each UF, can be estimated through: (Ramanathan, 2000):

$$PP_i = PA_i / ET_i \qquad (5)$$

where PP_i is the potential output of the i-th DMU and PA_i is the current output level.

Once efficiency indices are calculated, one can then attempt to identify some of the factors that determine their magnitudes. Technical efficiency indices (ET) and allocative efficiency indexes (EA) for the UFs might be related to human capital variables, with agroecological conditions or and with the use of irrigation.

Human capital can be measured in terms of the education of the rural population, more specifically, the years of schooling of individuals aged 5 year or older. These data are taken from Demographic Censuses (1970, 1980 and 1990); averages among the 1975 and 1985 censuses were used and data points for 1995 was estimated using growth rates in completed years of schooling over the 1970-85 period. The availability of technical assistance might also influence productivity; a variable to capture this form of human capital (based on the percentage of establishments that declared having access at those services) was derived from the 1995-96 Agricultural Census.

To capture agroecological and climatic conditions, a variable representing land quality was constructed based on the percentage of land within a given DMU that was of good or regular quality, and suitable for production with handling levels A and B, as classified by the Ministry of the Agriculture (Brazil, 1978 - 1980) that takes into account not just the soil, but also the climate conditions. Good-quality land did not face any significant production limitations. Regular-quality land could face moderate production limitations; such limitations can reduce productivity or substantially increase the need for inputs to overcome these limitations. 'Level A' handling is based in low-technological agricultural practices; practically there is no capital application for handling, improvement and soil conservation, and the agricultural practices depend on the manual work, could be used some animal traction with simple agricultural implements. 'Level B' handling is based on medium technological agricultural practices; it is characterized by the modest capital application and of research results for handling, improvement and soil conservation, with the agricultural practices conditioned to the animal traction. One would expect higher productivity from land suitable for production with such simple techniques, if cultivated with more modern methods.

Variables related to local weather conditions were also used to identify factors influencing agricultural inefficiency. Standard measures of rainfall and air temperature, and their interaction, along with the length of the growing period (captured by the latitude), supply a measure of water stress (the difference between potential and realized evapotranspiration) that was included as right hand side variable. Realized evapotranspiration is conditioned by the precipitation and by water stored in the soil. Measures of water stress can be obtained through the calculation of hydric balances (Ortolani et al., 1970).

Irrigation use was represented by the proportion of land irrigated in the UFs in 1995-96.

Since measures of technical and allocative efficiency take on values between zero and one, a Tobit estimation procedure (Maddala, 1983; Greene, 1995) was used to validate the initial OLS estimates.

2.2 - Data sources and variables used in estimating the production frontier

Crop-level data from the 1995-96 Agricultural Census for cotton (arboreal and herbaceous), peanuts, rice, bananas, potatoes, cocoa, coffee,cashews, sugar cane, onions, coconuts, beans, tobacco, jute, oranges, mallow, castor oil seeds, cassava, corn, pepper, sisal, soybeans, tomatoes, wheat and grapes were used to estimate production frontiers. Product price data were derived from the Fundação Getúlio Vargas (FGV) and IEA data bases. Aggregate agricultural output at the UF level was represented by a quantity index. A performance index was constructed base on the value of country-wide aggregate agriculture output in 1995. The "index-number problem" that emerges from such normalization was first identified by Fisher in his classic text published in 1922[10]. More recent literature has focused on the relationships among functional forms specified by researchers and index-numbers formulae. Diewert (1976) defined as flexible an aggregate functional form that can provide a second order approximation to an arbitrary homogeneous linear function; he also defined as superlative an index-number formula that is exact (i.e., consistent) for a flexible functional form. He demonstrated that the Törnqvist-Theil translog index is exact for an aggregative homogeneous translog form (and, therefore, superlative) and that the Fisher's formula is exact for a homogeneous quadratic aggregative function of order two (and, therefore, superlative).

Superlative formulae are also characterized by their second order approximations (Diewert, 1976)[11] that limit the range of measured variations, a property maintained for nonhomothetic functions (Diewert, 1978). However, in data series containing zero values, the estimates using the Törnqvist formula can be biased[12], hence, the Fisher formula was chosen and can be represented for each UF, by:

---

[10] Details in Silva and Carmo (1986).

[11] See Silva and Carmo (1986) for an empirical verification with São Paulo State data.

[12] For an analysis of that problem using Agricultural Census data see Vicente et al. (2001b).

$$FQ_{0,1} = \sqrt{\frac{\sum_{i=1}^{n} p_0^i q_1^i}{\sum_{i=1}^{n} p_0^i q_0^i} \cdot \frac{\sum_{i=1}^{n} p_1^i q_1^i}{\sum_{i=1}^{n} p_1^i q_0^i}} \qquad (6)$$

where, FQ is the Fisher output index for a given UF, superscript 'i' indexes product quantities (q) and prices (p), and subscript zero and one denote, respectively, national and UFs levels[13].

Output indices calculated using this methodology more adequately capture output changes than the value of production, are conceptually more consistent with the DEA framework, and have the added advantage of implicitly consider prices differences across the UFs, differences that would be lost if individual crop production data were used directly in calculating efficiency indices.

Inputs into production processes were: land (area dedicated to crops), labor (household labor, permanent and temporary employees, partners and other sources of farm labor), machines, fertilizers, pesticides, seeds and seedlings. Land rental rates and monthly salaries paid wage earners were derived from FGV and IEA sources.

Regarding mechanization, stocks of tractors and harvesters on farms were transformed into service flows using the Yotopoulos (1967) formula:

$$R_i = rV_i^{T_i} / 1 - e^{-rT_i}$$

where R is the constant annual service flow from the i-th asset, ViTi is the original market value, Ti is the expected life of the machine (21 years, in this case), r is the discount rate (set at the annual return on a commercial savings account, in this case). The average value of farm machinery at UF level, derived from Barros (1999) and Vicente et al. (2001a), took into consideration the Agricultural Census categories of tractor power (measured in terms of horse-power). Fuel usage was estimated using expenses on fuels as declared in the Agricultural Census and the average price of diesel (quantity = expenses/price).

Fertilizer use was estimated from declared expenses on base and top dressing fertilizers and the unit price of formula 04 - 14 - 08 (obtained

[13] The first ratio, inside of the root, is a Laspeyres index, and the second ratio is a Paasche index.

through the prices of sulfate of ammonia, simple superfosfate and potassium chloride at UF level).

Pesticides use was estimated based on declared expenses and of the prices of Folidol 60% (insecticide), Benlate 50% (fungicide) and Tordon 101 (herbicide), again at UF level.

Use of seeds and seedlings were based on declared expenses. Gaps in seed use data were filled using estimates based the prices of seed for cotton, garlic, rice, potatoes, onions, beans, hybrid corn, soybeans, sorghum and wheat, weighted by the amounts recommended per hectare (Pedro Jr., 1987) and the areas to these crops at UFs level. Although price data on coffee and orange seedlings exist, they were not used due to the absence of information on newly planted areas in the Agricultural Censuses[14].

Given the nature of the factors of production described above - most of which divisible and scale neutral - the restriction of variable returns to scale was not imposed in the DEA models, which will bias results towards increased technical efficiency for DMUs[15].

3 - Results and Discussion

The geometric mean[16] of economic efficiency indices for all UFs was 0,336. The Southeast, Center-west and South regions averages were higher than the national average. UFs in the North and Northeast regions had the lowest averages. These results were due mainly to indices of allocative efficiency; only the states of Bahia, Rio Grande do Norte, Paraná and Rio Grande do Sul had indices of allocative efficiency that were higher than their respective technical efficiency indices (table 1). Only the state of São Paulo registered an economic efficiency index equal to 1; Espírito Santo displayed moderate economic inefficiency, and the other UFs registered large measures of economic inefficiency[17].

---

[14] For more details on the calculation of the quantities and prices of the inputs see Vicente et al. (2001a).

[15] Naturally, in analyses at the farm's level, given the characteristics of the mechanization use, would be more appropriate to consider variable returns to scale.

[16] It was preferred to use geometric averages in the calculation of the indicators for the regions and for Brazil to maintain the property of decomposition of those indexes (that is, EE = ET.EA).

[17] Ray and Bhadra (1993) used an outline to classify violations, at firm level, of the weak axiom of costs minimization. Based on that outline, Pereira Fº and Ferreira Fº (2003) classified efficiency indices as: weak inefficiency ($0,9 \leq EE < 1,0$), moderate inefficiency ($0,7 \leq EE < 0,9$) and strong inefficiency ($EE < 0,7$); in accordance with Ray and Bhadra (1993), the efficient class ($EE = 1$) can be added.

Table 1 - Technical, allocative and economic efficiencies indices, and output indices, UFs and Regions, Brazil, 1995.

Units of the Federation/Region ([1])	Efficiency Index			Output Index ([2])		
	technical	allocative	economic	observed	frontier([3])	difference (%)
Alagoas	0,919	0,420	0,386	1,94	2,12	8,81
Bahia	0,392	0,538	0,211	4,54	11,59	155,10
Ceará	0,504	0,283	0,143	1,31	2,60	98,41
Paraíba	0,668	0,351	0,234	1,08	1,61	49,70
Pernambuco	0,828	0,350	0,290	2,56	3,09	20,77
Piauí	0,321	0,227	0,073	0,46	1,42	211,53
Rio Grande do Norte	0,297	0,590	0,175	0,44	1,49	236,70
Sergipe	0,636	0,344	0,219	0,56	0,87	57,23
Maranhão	0,406	0,236	0,096	1,07	2,63	146,31
Northeast	0,513	0,353	0,181	13,96	27,43	96,49
Acre	1,000	0,223	0,223	0,15	0,15	0,00
Amapá	0,739	0,304	0,225	0,02	0,03	35,32
Amazonas	1,000	0,241	0,241	0,67	0,67	0,00
Pará	0,741	0,259	0,192	1,14	1,53	34,95
Roraima	0,750	0,429	0,322	0,08	0,10	33,33
Rondônia	1,000	0,389	0,389	0,70	0,70	0,00
Tocantins	0,756	0,466	0,352	0,29	0,39	32,28
North	0,846	0,318	0,269	3,04	3,57	17,24
Distr. Federal	0,883	0,635	0,561	0,16	0,18	13,25
Goiás	0,927	0,728	0,675	4,34	4,68	7,87
Mato Grosso	1,000	0,607	0,607	4,59	4,59	0,00
Mato Grosso do Sul	0,906	0,689	0,624	2,48	2,74	10,38
Center-West	0,928	0,663	0,615	11,57	12,19	5,36
Minas Gerais	0,801	0,701	0,561	13,02	16,26	24,84
Espírito Santo	1,000	0,898	0,898	3,97	3,97	0,00
Rio de Janeiro	0,813	0,655	0,533	0,69	0,85	23,00
São Paulo	1,000	1,000	1,000	22,78	22,78	0,00
Southeast	0,898	0,801	0,720	40,45	43,85	8,39
Paraná	0,718	0,748	0,537	13,46	18,75	39,28
Santa Catarina	0,671	0,622	0,417	4,57	6,80	49,03
Rio Grande do Sul	0,683	0,697	0,476	12,95	18,96	46,41
South	0,690	0,687	0,474	30,97	44,51	43,70
Brazil	0,723	0,465	0,336	100,00	131,55	31,55

([1]) To Brazil and Regions, the efficiency indices are the geometric averages and the outputs are sums of the respective UFs.
([2]) Performance indices were calculated using Fisher's formula.
([3]) Observed output index / technical efficiency index.
Source: research data.

At national level, technical efficiency indices averaged 0,723; above-average measures are reported for the Center-West, Southeast and North regions. The Southeast, South and Center-West regions registered measures of allocative efficiency that were above the national average (0,465).

UFs in the Southeast (São Paulo and Espírito Santo), Center-West (Mato Grosso) and North (Acre, Amazon and Rondônia) - with indices of technical efficiency equal to 1 - demonstrate the simultaneous existence of technically efficient production in UFs characterized by very established and modernized agriculture, in quickly modernizing UFs, and in UFs in which more traditional crop production systems are dominant.

The allocative efficiency indices, on the other hand, show strong inefficiency in almost all of areas of the country, except in the Southeast. Only São Paulo (efficiency = 1), Espírito Santo, Paraná, Goiás and Minas Gerais (with moderate inefficiency) displayed relatively high allocative efficiency measures. Structural problems - perhaps associated with inadequate research, technical support and education, poorly performing factor and product markets, and inappropriate agrarian structure, among others - may be reducing the efficiency of agricultural production in other areas of the country.

Given these technical efficiency indices and using the production frontier, it is possible to estimate what crop product might have been if all producers used the same levels of inputs but use them efficiently. The DEA model suggests that national crop production in 1995could have been about 31,6% higher, but again, the range of possible efficiency gains displayed substantial spatial variation. More specifically, the Center-west could have produced 5,4% more, and the Northeast could have boosted output by 96,5%[18].

[18] Note that technical efficiency indices can suffer accentuated influence of the edafoclimatic conditions.

[19] Scales with categorical measures were based on judgments of ordered intensity and in semantic opposition around a medium point (Furtado, 2003).

Tabela 2 – Likert-Scale Indicators of Input Underutilization/ Overutilization, UFs and Regions of Brazil, 1995

Units of the Federation / Region	Input (1) land	work	machines	Fuels	fertilizers	herbicides	insecticides	fungicides	seeds
Alagoas	-1	-1	1	0	1	1	1	1	1
Bahia	-1	-1	0	1	0	1	1	1	-1
Ceará	-1	-1	1	1	1	1	1	1	1
Paraíba	-1	-1	1	1	1	1	1	1	0
Pernambuco	-1	-1	1	1	1	1	1	1	1
Piauí	-1	-1	1	1	1	1	1	1	0
R. Gde. do Norte	-1	-1	-1	-1	-1	-1	-1	-1	-1
Sergipe	-1	-1	1	1	1	1	1	1	0
Maranhão	-1	-1	1	1	1	1	1	1	0
Northeast (avg)	-1	-1	0,67	0,67	0,67	0,78	0,78	0,78	0,11
Acre	0	-1	1	1	1	1	1	1	1
Amapá	-1	-1	0	-1	0	1	1	1	-1
Amazonas	-1	-1	1	1	1	1	1	1	1
Pará	-1	-1	1	1	1	1	1	1	1
Roraima	-1	-1	0	-1	1	-1	-1	-1	-1
Rondônia	-1	-1	0	0	1	-1	-1	-1	0
Tocantins	-1	-1	0	-1	1	0	0	0	-1
North (avg)	-0,86	-1	0,43	0	0,86	0,29	0,29	0,29	0
Distr. Federal	-1	0	-1	0	-1	-1	-1	-1	-1
Goiás	-1	0	0	0	0	0	0	0	-1
Mato Grosso	-1	0	0	-1	-1	-1	0	0	-1
M. Grosso Sul	-1	0	0	-1	-1	-1	-1	-1	-1
Center-West (avg)	-1	0	-0,25	-0,50	-0,75	-0,75	-0,50	-0,50	-1
Minas Gerais	0	-1	0	1	0	1	1	1	0
Espírito Santo	0	-1	1	1	1	1	1	1	1
Rio de Janeiro	-1	-1	0	0	1	1	1	1	1
São Paulo	0	0	0	0	0	0	0	0	0
Southeast (avg)	-0,25	-0,75	0,25	0,50	0,50	0,75	0,75	0,75	0,50
Paraná	-1	-1	-1	0	0	0	-1	0	-1
Santa Catarina	0	-1	-1	1	0	0	0	0	-1
R. Gde. do Sul	-1	-1	-1	0	0	0	0	0	-1
South (avg)	-0,67	-1	-1	0,33	0	0	-0,33	0	-1
Brazil (avg)	-0,82	-0,79	0,21	0,23	0,37	0,29	0,30	0,34	-0,18

(1) For Brazilian UFs: -1 = overutilization; 0 = adequate level; +1 = underutilization. Regional and national averages were interpreted according to the Likert scale explained in the text.
Source: research data.

Other indicators of allocative efficiency related to input over- or underutilization can also be calculated, maintained the same output levels. For example, a Likert scale[19] was built by attributing a zero value to recommendations of alteration input use between ± 30%, a value of -1 to recommendations for decreased input use that are larger than 30% (overutilization), and a value +1 to recommendations for increased use that are larger than 30% (underutilization). Regional and national averages were interpreted using other Likert scale[20]. At national level, the results indicate strong land and labor overutilization, and modest fertilizer and pesticide underutilization (herbicides, insecticides and fungicides, Table 2).

Several regional results differ of the national averages: the Northeast suffered from moderate machine, fuel and fertilizer underutilizations, and strong pesticide underutilization; the North experienced weak machine underutilization and strong fertilizer underutilization; the Center-West correctly used of labor, weakly overutilized fuel, insecticides and fungicides, moderately overused fertilizers and herbicides, and strongly overutilized seeds[21]; the Southeast, correctly used of land, moderately overused labor, weakly underutilized fuel, fertilizers and seeds, and moderately underutilized pesticides; and, the South moderately overutilized land, strongly overutilized machines and seeds, weakly overutilized insecticides, correctly used fertilizers, herbicides and fungicides, and weakly underutilized fuel[22].

Of the explanatory variables included to try to explain differences in technical efficiency levels[23] across the UFs, only the agroecological factors and irrigation use were statistically significant, indicating that

---

[20] $I < -0{,}75$ strong overutilization; $-0{,}75 \leq I < -0{,}50$ moderate overutilization; $-0{,}50 \leq I < -0{,}25$ weak overutilization; $-0{,}25 \leq I \leq 0{,}25$ correct use; $0{,}25 < I \leq 0{,}50$ weak underutilization; $0{,}50 < I \leq 0{,}75$ moderate underutilization, and $0{,}75 < I$ strong underutilization.

[21] This result can be portraying higher relative prices of those inputs.

[22] That looks like contradiction, between strong overutilization of machines and weak underutilization of fuels is due, probably, to the transformation method of machines stock in flow; however, can also be an indicator of excessive tractors and harvesters stock in relation to the effective use, acted by the fuels expenses

[23] The statistically significant σ values in the Tobit models indicate that the estimates differ from those of ordinary least squares, although drastic alterations are not observed in the coefficients.

production and crop production efficiency were strongly influenced by climate and soils (Table 3).

The estimated coefficient for the hydric deficiency of the September-March period, although with the expected negative sign, is not statistically significant. It is probable that a better definition of that variable, considering differences in the planting and vegetative development periods of the UFs crops supply would generate better results[24].

The unexpected absence of significant effect of the access to the technical assistance on the indices of technical efficiency is due, probably, to the inexistence of information about frequency and quality of the technical visits to the producers.

In a second model specified to identify factors influencing allocative efficiency only education of the rural population was statistically significant. In that case, higher levels of educational achievement led to greater efficiency, perhaps due to education's contributions to greater access to and ability to work with information on relative prices, and a greater appreciation for the possibilities for substitution among inputs in production[25].

The same explanation about the absence of statistically significant effect from technical assistance mentioned earlier applies here.

[24] It is also due to the fact that, as mentioned earlier, the measure of edafoclimatic aptitude incorporates hydric restrictions.

[25] The presence of heteroscedasticity was tested in both models using a Pesaran-Pesaran F-test (Matos, 2000); we could not reject the null hypothesis regarding the absence of heteroscedasticity.

Table 3 - Main results of the regression analysis of factors influencing efficiency indices, Brazil, 1995

Explanatory Variable	Dependent Variable							
	Technical Efficiency				Allocative Efficiency			
	coefficient		t (1)		coefficient		t (1)	
	OLS model							
Intercept	0,4870		1,813	c	0,0199		0,008	
Education	0,0010		0,018		0,1340		2,381	b
Edafoclimatic Aptitude	0,0069		2,367	b	0,0156		0,548	
Hydric Deficiency	-0,0003		-1,211		0,0000		0,001	
Technical Assistance	-0,0040		-1,242		-0,0003		-0,940	
Irrigation	1,3350		1,892	c	0,7450		1,082	
R^2	0,539				0,569			
$F_{(5,21)}$	4,905	a			5,534	a		
$F_{(1,25)}$ of Pesaran-Pesaran	0,211				2,655			
	Tobit model							
Intercept	0,5819		1,931	b	-0,0182		-0,076	
Education	-0,0252		-0,362		0,1359		2,645	a
Edafoclimatic Aptitude	0,0084		2,668	a	0,0018		0,689	
Hydric Deficiency	-0,0005		-1,597		0,0000		0,059	
Technical Assistance	-0,0051		-1,456		-0,0003		-0,089	
Irrigation	1,3843		1,858	c	0,7346		1,169	
σ	0,172	a			0,146	a		

(1) Significance levels: a = 1%; b = 5%; c = 10%.

Source: research data.

4 - Conclusions and Suggestions

National efficiency indices revealed moderate technical inefficiency in crop production in Brazil in 1995. Overall technical efficiency was found in UFs with modern agriculture, in UFs in the process of rapid modernization and in some UFs where traditional crop production was predominant. Technical efficiency was explained primarily by soil and climatic conditions and irrigation. If all UFs were to produce at the technically efficiency frontier, the nation crop production could increase by more than 30%.

Regarding allocative efficiency, national average demonstrated large inefficiencies in production; these inefficiencies were present in all regions of Brazil, except the Southeast. Educational achievement in rural areas was statistically linked to efficiency measures - more education was correlated with improved allocative efficiency. Simulations of cost minimization indicated that land and labor were generally overutilized and that fertilizers and pesticides generally underutilized in Brazil.

Economic efficiency indices in the UFs were determined mainly by measures of allocative efficiency (rather than technical efficiency) in nearly all cases; crop production in São Paulo was the only case for which economic inefficiency was not detected.

These results evidence agroecological zonings importance, as well as investments in education, to increase efficiency in agricultural production.

The considerable regional efficiency differences founded here suggests that further studies could verify if that pattern repeats at different farm sizes level.

Concerning to the efficiency levels explanatory models, new researches should try to test influence of scientific knowledge investments results, besides variables capable to represent rural extension and weather conditions more appropriately.

5 - References

BARROS, A.L.M. **Capital, produtividade e crescimento da agricultura**: o Brasil de 1970 a 1995. Piracicaba, ESALQ/USP, 1999. (Tese de Doutorado)

BRASIL. Ministério da Agricultura. Secretaria Nacional de Planejamento Agrícola. **Série Aptidão Agrícola das Terras**. Brasília: BINAGRI, 1978-1980.

CENSO AGROPECUÁRIO 1995-1996. Rio de Janeiro: IBGE, 1998.

CENSO DEMOGRÁFICO. Rio de Janeiro: IBGE, 1970, 1980, 1990.

CHARNES, A.; COOPER, W.; RHODES, E. Measuring the efficiency of decision making units. **European Journal of Operational Research**, v. 2, n. 6, p. 429-444, 1978.

COELLI, T. A Guide to DEAP Version 2.1: a Data Envelopment Analysis (Computer) Program. Armidale: University of New England/ Department of Econometrics/Centre for Efficiency and Productivity Analysis, 1996. (CEPA Working Paper 96/08)

DIEWERT, W.E. Exact and superlative index numbers. **Journal of Econometrics**, v. 4, n. 2, p. 115-145, may 1976.

DIEWERT, W.E. Superlative index numbers and consistency in aggregation. **Econometrica**, v. 46, n. 4, p. 883-900, jul. 1978.

FARRELL, M.J. The measurement of productive efficiency. **Journal of Royal Statistical Society**, A, n. 120 (Part 3), p. 253-281, 1957.

FØRSUND, F.R.; LOVELL, C.A.K.; SCHMIDT, P. A survey of frontier productions functions and of their relationship to efficiency measurement. **Journal of Econometrics**, v. 13 n. 1, p. 5-25, may. 1980.

FURTADO, A. T. (coord.) **Políticas Públicas para a Inovação Tecnológica na Agricultura do Estado de São Paulo**: métodos para a avaliação de impactos da pesquisa. Campinas: UNICAMP/IE/DPCT/GEOPI, mai. 2003. (Relatório Final de Atividades - Programa de Políticas Públicas - FAPESP)

KOPP, R.J. The measurement of productive efficiency: a reconsideration. **The Quarterly Journal of Economics**, v. 96 n. 3, p. 477-503, aug. 1981.

LOVELL, K.C.A. Production frontiers and productive efficiency. In: FRIED, H.O; LOVELL, K.C.A.; SCHIMIDT, S.S. (ed.) **The Measurement of Productive Efficiency**: techniques and applications. New York: Oxford University Press, 1993. p. 3-54.

MATOS, O. C. **Econometria Básica**: teoria e aplicações. São Paulo: Atlas, 2000. (3ª ed.)

ORTOLANI, A.A. et al. **Parâmetros Climáticos e a Cafeicultura**. Rio de Janeiro: IBC, 1970.

PEDRO Jr., M.J. et al. **Instruções Agrícolas para o Estado de São Paulo**. Campinas: IAC, 1987. (4ª ed., Boletim 200)

PEREIRA Fº, C.A.; FERREIRA Fº, J.B.S. Fontes de ineficiência da pequena produção familiar agrícola na região Recôncavo do Estado da Bahia. **Revista de Economia e Sociologia Rural**, v. 41 n. 1, p. 63-78, jan./mar. 2003.

RAMANATHAN, R. **Data Envelopment Analysis (DEA)**. Helsinki: Helsinki University of Technology, sep./dec. 2000. (Class Notes)

RAO, D.S.P.; COELLI, T.J. **Economic Growth, Productivity Change and Inequalty**: methodology for the assessment of economic performance of nations. Armidale: University of New England/ Department of Econometrics/Centre for Efficiency and Productivity Analysis, aug. 1999. (Background paper for the Workshop at the Kanda Campus of Senshu University on 24th August, 1999)

RAY, S.C.; BHADRA, D. Nonparametric tests of cost minimizing behavior: a study of Indian farms. **American Journal of Agricultural Economics**, v.75 n.4, p. 990-999, nov. 1993.

SCHULTZ, T.W. **A Transformação da Agricultura Tradicional**. Rio de Janeiro: Zahar, 1965.

SCHULTZ, T.W. The value of the ability to deal with disequilibria. **Journal of Economic Literature**, 13(3): 827-846, sep. 1975.

SCHUMPETER, J.A. T**eoria do Desenvolvimento Econômico**: uma investigação sobre lucro, capital, juro e o ciclo econômico. São Paulo: Abril Cultural, 1982.

SEIFORD, L.M.; THRALL, R.M. Recent developments in DEA: the mathematical programming approach to frontier analysis. **Journal of Econometrics**, v. 46, n. 1/2, p. 7-38, oct./nov. 1990.

SILVA, G.L.S.P.; CARMO, H.C.E. Como medir a produtividade agrícola: conceitos, métodos e aplicações no caso de São Paulo. **Agricultura em São Paulo**, v. 33 , n. 1/2, p. 139-170, 1986.

TUPY, O. et al. Eficiência econômica na produção de leite tipo B no Estado de São Paulo. **Informações Econômicas**, v. 33 , n. 2, p. 14-20, fev. 2003.

VICENTE, J.R. **Pesquisa, Adoção de Tecnologia e Eficiência na Produção Agrícola**. São Paulo: APTA, 2002. (Série Discussão APTA 2)

VICENTE, J.R. Tecnologia, eficiência e produtividade total de fatores na agricultura brasileira, 1970-95. In: CONGRESSO BRASILEIRO DE ECONOMIA E SOCIOLOGIA RURAL, 41. Juiz do Fora, MG, 27 a 30 de julho de 2003. **Anais**. Brasília: SOBER, 2003. p1-17. (CD-Rom)

VICENTE, J.R.; ANEFALOS, L.C.; CASER, D.V. Produtividade agrícola no Brasil, 1970-95. **Agricultura em São Paulo**, v. 48 , n. 2, p. 33-55, 2001a.

VICENTE, J.R.; ANEFALOS, L.C.; CASER, D.V. Vieses no cálculo de números-índices utilizando a fórmula de Törnqvist em séries com ausências de dados. **Informações Econômicas**, v. 31 , n. 6, p. 45-48, jun. 2001b.

VICENTE, J.R.; ANEFALOS, L.C.; CASER, D.V. Relações de troca da agricultura brasileira, 1970-1995. **Informações Econômicas**, v. 31, n. 11, p. 17-25, nov. 2001c

YOTOPOULOS, P.A. From stock to flow capital inputs for agricultural production functions: a micro-analytic approach. **Journal of Farm Economics**, v. 49, n. 2, p. 476-491, may 1967.

Recebido em agosto de 2003 e revisto em março de 2004.