REVISTA CONTRIBUCIONES A LAS CIENCIAS SOCIALES

Technical efficiency of the Family Health Program (Psf) on the health of vulnerable municipalities in the northeast region, Brazil

Eficiência técnica do Programa de Saúde da Família (PSF) na saúde de municípios vulneráveis na região nordeste, Brasil

Eficiencia técnica del Programa Salud de la Familia (PSF) en la salud de municipios vulnerables de la región nordeste, Brasil

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Francisco José Silva Tabosa
PhD in Economics
Institution: Universidade Federal do Ceará (UFC)
Address: Fortaleza - Ceará, Brasil
E-mail: franzetabosa@ufc.br

Pablo Urano de Carvalho Castelar
PhD in Economics
Institution: Universidade Federal do Ceará (UFC)
Address: Fortaleza - Ceará, Brasil
E-mail: pcastelar@ufc.br

Domingos Isaias Maia Amorim
PhD student in Applied Economics
Institution: Universidade de São Paulo (USP)
Address: Piracicaba - São Paulo, Brasil
E-mail: domingos_isaias@hotmail.com

Eucinete Menezes Albuquerque
PhD student in Rural Economics
Institution: Universidade Federal do Ceará (UFC)
Address: Fortaleza - Ceará, Brasil
E-mail: eucinetemenezes@gmail.com

Laura Cunha Rebouças Lessa
PhD student in Rural Economics
Institution: Universidade Federal do Ceará (UFC)
Address: Fortaleza - Ceará, Brasil
E-mail: laura_crlessa@alu.ufc.br

Erika Costa Sousa
PhD student in Rural Economics
Institution: Universidade Federal do Ceará (UFC)
Address: Fortaleza - Ceará, Brasil
E-mail: erikacosta@alu.ufc.br

ABSTRACT
The objective of this study was to analyze the technical efficiency of the Family Health Program (PSF) in the health indicators of the most vulnerable municipalities in the Northeast region. For this, the stochastic frontier method was used. The results showed that the variables related to the PSF (Consultations and PSF Team) were efficient in reducing total and infant mortality; as well as the variables GDP per capita and presence in the Mais Médicos Program (PMM) in the region

Keywords: Family Health Program (PSF), northeast region, stochastic frontier.

RESUMO
O objetivo deste estudo foi analisar a eficiência técnica do Programa Saúde da Família (PSF) nos indicadores de saúde dos municípios mais vulneráveis da região Nordeste. Para isso, foi utilizado o método de fronteira estocástica. Os resultados mostraram que as variáveis relacionadas ao PSF (Consultas e Equipe PSF) foram eficientes na redução da mortalidade total e infantil; assim como as variáveis PIB per capita e presença no Programa Mais Médicos (PMM) na região.

Palavras-chave: Programa Saúde da Família (PSF), região nordeste, fronteira estocástica.

RESUMEN
El objetivo de este estudio fue analizar la eficiencia técnica del Programa Salud de la Familia (PSF) en los indicadores de salud de los municipios más vulnerables de la región Nordeste. Para ello, se utilizó el método de la frontera estocástica. Los resultados mostraron que las variables relacionadas con el PSF (Consultas y Equipo PSF) fueron eficientes en la reducción de la mortalidad total e infantil; así como las variables PIB per cápita y presencia en el Programa Más Médicos (PMM) en la región.

Palabras clave: Programa de Salud de la Familia (PSF), región nordeste, frontera estocástica.

1 INTRODUCTION

The Family Health Program (PSF) was introduced by the Ministry of Health in 1994, with the objective of reorganizing health care, especially for the most vulnerable groups (areas with poor, rural and low-income populations), promoting better conditions for life and assistance to registered families, where the teams work in basic health units, residences and with mobilizations in the communities (Santos and Jacinto, 2017).

According to Santos and Jacinto (2017), in 2007, the PSF was present in 92.1% of municipalities in Brazil. The coverage area went from 4% in 1998 to 62% of the Brazilian population in 2015. According to Silva et al (2019), the PSF acted directly in reducing the infant mortality rate in Brazil, from 21.14% in 2000 to 15.71% in 2007. However, in the Northeast region, this reduction was more accentuated, going from 26% to 19% (Roncalli and Lima, 2006). These results drew attention in the reduction of infant mortality rates, and of other age groups (Rocha and Soares, 2010), as well as in rural areas (Santos and Jacinto, 2017). Several new studies on the program were developed to confirm the effectiveness of the PSF in Brazil.

Aquino et al (2009) found that the increase in PSF coverage led to a reduction in the infant mortality rate in Brazilian municipalities between 1996 and 2004. Studies developed by Macinko et al (2006), Rocha and Soares (2008), Santos and Jacinto (2017) and Silva et al (2019) showed through various techniques of public policy evaluation, that the PSF presents itself as a program of great relevance in reducing the infant mortality rate in Brazil.

Silva et al (2019) found an inverse trajectory between the infant mortality rate and PSF coverage in the Northeast region. In other words, the greater the expansion of the program, the lower the infant mortality rate in the region. Also according to the authors, the Northeast showed the greatest reduction in the infant mortality rate, from 26% in 2000 to 17% in 2005, with a PSF coverage rate, in the same year, of 58.7%.

Roncalli and Lima (2006) evaluated the PSF on child health indicators in municipalities in the Northeast region with more than 100,000 inhabitants, but the results did not show significant differences between covered and non-covered areas, only with the indicator hospitalization rate for diarrhea. However, can these results be divergent when the study area is in more vulnerable municipalities in the region?

Thus, this study proposes to analyze the technical efficiency of the Family Health Program (PSF) in the health indicators of the most vulnerable municipalities in the Northeast region. For this, the stochastic frontier method was used. The year chosen was 2015, due to the information collected in DATASUS.

The study consists of 4 sections, in addition to the introduction. Section 2 addresses the topic of productivity and efficiency. Section 3 presents the methodology used. Section 4 presents the results found in the study. The conclusion ends the study.

2 PRODUCTIVITY AND EFFICIENCY

The production models used most often consider a technology that produces a single product, which is commonly described by a production function, f(x). However, the properties of the production set validated by economic theory apply directly to the production function.

In view of the above, it is then possible to define the production function or production frontier, *f (x)*, as that which describes the technical relationship between the inputs and the outputs of a production process, defining the maximum output attainable from of a given input vector, that is:

$$f(x) = \{y \in R\text{: y is the maximum output associated with }-x\text{ in y}\} \quad (1)$$

Considering the diverse types of production functions, the Cobb-Douglas and the Translogarithmic functions can be listed as two of the main ones. The first is a type of function widely used in microeconomic analysis, and can be described as follows:

$$y = f(x_1, x_2, \dots x_n) = a_0 x_1^{b_1} x_2^{b_2} \dots x_n^{b_n} \quad (2)$$

The Cobb-Douglas function is easy to estimate and manipulate mathematically, but it is restrictive in relation to the properties imposed on the production structure (the value of the returns to scale and the elasticity of substitution is equal to the unit). Formulation of the Cobb-Douglas function is often not satisfactory to represent certain production processes. In such cases, it is common to adopt a more flexible formulation, adjusting to a function of the translogarithmic type (or Translog), namely:

$$lny = a_0 + \sum_{i=1}^{n} a_{\,1} \ln x_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{i=1}^{n} b_{ij}\, lnx_i\, lnx_j \quad (3)$$

The Translog function does not impose restrictions on the production structure, but it is more difficult to manipulate mathematically, as it reduces the degrees of freedom and presents problems of multicollinearity.

Works on productivity and efficiency in economics began with the work of Farrel (1957), who focused on measuring efficiency according to the use of inputs. One can, thus, examine the sources of productivity growth over time and the differences in productivity between countries and regions.

Productivity growth can be defined as the net change in output due to changes in efficiency and technological changes, where the former is the variation of the output observed in relation to its frontier, and the latter represents the displacement of the frontier of production (TUPY & YAMAGUCH, 1998). Rivera and Constantin (2007), stated that not all producers are technically efficient, that is, not all producers are able to use the minimum quantity of inputs required to produce the desired output quantity, given the available technology. In general, research scholars use index numbers to analyze productivity growth without distinguishing the factors that caused the changes, that is, if this increase occurred only due to the increase in the use of inputs, or if there were variations in technical efficiency or technological variations (CARVALHO, 2003).

Both efficiency and productivity are indicators of success, performance measures, through which productive units are evaluated. This performance, in turn, is a function of two factors: the state of the technology and the degree of efficiency of its use. The technology defines the frontier relationship between inputs and outputs, while the efficiency incorporates waste and misallocation of resources related to this frontier (CARVALHO, 2003).

Farrel (1957) states that the study of efficiency and productivity has become important because this is the main step in a process that can lead to substantial savings in resources, which is of great importance for companies in competitive environments. Thus, the relationship between the quantity produced and the quantity used of inputs can be used as a measure of the firm's performance. The highest values of this ratio are associated with the best performances (highest productivity).

Farrel (1957) argues that, in the traditional approach, the measure of productivity assumes that the production obtained results from the best practice or is the frontier production (maximum production possible, given the quantities of inputs used). This assumption assumes that the production observed throughout the period is technically efficient in the sense of Farrel (1957). On the other hand, in contrast to the traditional approach, the frontier approach to measuring productivity explicitly incorporates inefficiency and computes changes in efficiency (GROSSKOPF, 1993).

When there is an increase in productivity of the production unit between two periods of time, this increase can be attributed to technological variations, efficiency gains, exploitation of economies of scale or the combination of all these factors. Therefore, variations in technical efficiency are understood as changes in the distance of the observed product in relation to its border. Therefore, technological variations involve advances in technology, which can be represented by an upward shift in the production frontier.

2.1 MEASURING EFFICIENCY

Among the most common methods for measuring the efficiency of production units, two of them stand out in most studies on productivity and efficiency. The first is the statistical (or econometric) approach, and the second is the mathematical (deterministic) approach, being the two approaches quite different.

Segunpta (1999) states that the econometric approach, for using a certain functional form for the function (for example, Cobb-Douglas), is parametric, that is, the estimation of the efficiency of the production technology is done through parameters, tested from standards. However, there are some disadvantages to using this approach. The error of bad specification can occur, often caused by the functional form of the production function. Furthermore, the measurement of efficiency in which there are multiple inputs and multiple products is not easily applied in a parametric model. In this sense, the most appropriate approach is the Data Envelopment Analysis (DEA). In the DEA approach, linear programming methods are used to calculate the efficiency boundary. Consequently, this approach avoids misspecification errors.

The disadvantages of the DEA model, according to Geva-May (2001), is that, first, it does not provide estimates or tests of significance of the parameters; second, the envelope boundary can be defined only for small samples. Other factors can influence the results obtained through the DEA approach, such as, for example, the heterogeneity of the production units and the fact that the DEA considers that all deviations to the frontier are treated as inefficiency.

3 METHODOLOGY

3.1 DATA

This study consider the spending from public policies performed by municipalities most vulnerable in the Northeast region [1] related to health. The data are collected from the year 2015 Data for output and outcomes in the health area were obtained from DATASUS[2].

Specifically, the selected indicators in the health area: Consultas (number of consultations carried out in the municipality); Equipe PSF (Number of professionals who are part of the municipality's PSF); PIBpc (municipal GDP per capita); PMM (dummy variable, where 1 indicates that the municipality adhered to the Mais Médicos Program – PMM- and 0 otherwise); and Outcome Indicators: TxMort (Mortality Rate per thousand live births) and TxMInf (Infant Mortality Rate per thousand live births).

Table 1 presents the descriptive statistics of the variables used in this study in 2015. Note that the average number of consultations carried out by the PSF in the selected municipalities is 861. The average number of professionals working in the PSF in the municipalities is 11, 25. The average GDP per capita of the municipalities is R$9,897.28 per year; while 66% of the selected municipalities joined the Mais Médicos Program (PMM).

Table 1: Descriptive statistics of the series in the health area: 2015.

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
Consultas	448	861,01	586,73	28,94	12.303
Equipe PSF	448	11,25	8,95	7	91
PIBpc	448	9.897,28	10.313	3.089,54	219.775,48
TxMort	448	186,26	297,47	11	4.045
TxMinf	448	6,80	11,04	1	139
PMM	448	0,66	0,58	0	1

Source: DATASUS and STN. Prepared by the authors.

3.2 STOCHASTIC FRONTIER MODEL

As featured and discussed in Stead et al. (2019), the stochastic frontier model is typically used to estimate best practice ‘frontier’ functions that explain production or cost and predict firm efficiency relative to these. A key feature of these models, as argued by the authors, is the focus on unobserved disturbance in the econometric model. This entails a deconvolution of the

[1] The municipalities were chosen through a ranking of the HDI-health for the year 2010. The 25% of the municipalities in the region that presented the lowest levels of HDI-health were selected.
[2] www.datasus.gov.br .

disturbance into a firm inefficiency component, where the quantification of which is the goal of the analysis, and a statistical noise term (STEAD ET AL., 2019).

The stochastic frontier approach allows for shifts from the frontier to represent both inefficiency and an unavoidable statistical noise, with the aim of being a closer approximation to reality, since observations usually involve random errors.

Coelli *et al.* (1998) define the production function of a production unit *i* in period *t* as:

$$y_{it} = \exp\left(x_{it}\beta + v_{it} - u_{it}\right) \qquad (4)$$

This production function can be rearranged in the following way:

$$y_{it} = \exp(x_{it}\beta + v_{it})\exp(-u_{it}) \qquad (5)$$

or

$$lny_{it} = x_{it}\beta + v_{it} - u_{it} \qquad (6)$$

In which:

y_{it} is the vector of produced quantities (*outputs*);
x_{it} is the vector of inputs used in production (*inputs*);
β is the vector of coefficients to be estimated (parameters);

The terms v_{it} and u_{it} are vectors representing different components of the error term. The first one refers to the random part of the error, with normal distribution, independent and identically distributed, truncated at zero and with constant variance σ^2, ($v \sim$ iid N $(0,\sigma^2_v)$), while the second term represents technical inefficiency, that is, the part that constitutes a downward deviation from the frontier of production, which can be inferred by the negative sign and by the restriction $\mu \geq 0$. They are non-negative random variables with normal distribution truncated at zero, independently distributed (not identically) with mean μit and constant variance σ^2_u , *i.e.*, ($u \sim$ NT (μ, σ^2_u). The error components are independent of each other and x_{it} is supposed to be exogenous, so the model can be estimated by the maximum likelihood technique (ARAÚJO, FEITOSA, SILVA, 2014)

The maximum likelihood function was reparameterized in terms of the parameter $\gamma = \sigma_u / (\sigma_u + \sigma_v)$ so that the effects of the technical inefficiency of the model can be verified by means of statistical tests. If γ is considered statistically equal to zero, there is no influence of the technical inefficiency in the model, thus being possible to apply ordinary least squares for the estimation of the parameters. The closer γ is to one, the greater the importance of technical inefficiency in the model.

The main advantage of considering a stochastic frontier analysis is that, unlike other methods, it introduces an error component to represent noise, measurement errors. Moreover, it allows the decomposition of the deviation of an observation into two components: random noise and the effects of technical inefficiency of production (CARVALHO, 2003).

Coelli *et al.* (1998) justifies the choice of parametric models by means of some properties, which are:

i) the possibility of performing hypothesis tests on the parameters of the explanatory variables;

ii) the possibility of including control variables to explain technical inefficiency in only one stage;

iii) allows the presence of random noise in the environment in which the decision-making unit operates.

For Souza *et al.* (2010), although the stochastic frontier of production model presents the advantages described in the properties summarized by Coelli *et al.* (1998), this model requires the imposition of an *a priori* functional form and the performance of a test of hypotheses concerning the distribution of the term of inefficiency. Also, according to Pal (2004), the question of relation between the noise variable and the inefficiency error can be raised. The random shock leading to higher output could influence management to become more efficient. Nevertheless, it is possible to test if there is any correlation between the two error components.

Nonparametric models, such as the DEA model, do not require such restraints. When assuming constant returns of scale, as is the case of the present work for the reasons explained in the following section that discusses the test for the functional form, the two methodologies, stochastic frontier of production and DEA, provide the same result[3], so this work will focus on using the first methodology only. The main objective of the model is the estimation of a production function in terms of its factors of production. In this sense, the maximum production can be obtained by employing a certain efficient combination of factors. However, there is no guarantee that an efficient combination of factors will be used to maximize production. Considering the possibility of technical inefficiencies, the results can be featured below the maximum frontier of production. Hence the origin of the stochastic production function model.

3.2.1 Hypotheses tests

3.2.1.1 Functional form test

Some hypothesis tests concerning the estimation of the stochastic frontier are relevant, since the estimation is based on the statistical (econometric) approach. As described in previous sections, parametric estimation of the frontier requires that the production function assume a functional form, which can be determined by means of the Generalized Likelihood Ratio Test. Initially, the production function is estimated in the Cobb-Douglas form and then in the Translog form, so that it is possible to compare the two functions through the Functionality Test, in order to identify the more appropriate functional form to be used in the model. This procedure is well defined in recent works by Araújo *et al.* (2014) and Feitosa *et al.* (2014).

The functionality test aims to verify the null hypothesis that the Cobb-Douglas form is the most appropriate functional form to represent the data, given the specifications of the Translog Function. After the estimation of the two models mentioned above, the respective log-likelihood (LL) values are verified, and from the value of the Generalized Likelihood (LR) statistic, the following test of hypothesis is performed: H_0: Cobb-Douglas; H_1: Translog.

Thus, the Generalized Likelihood Ratio (RL) test is determined as follows:

$$LR = -2\,[\ln LL(H_0) - \ln LL(H_1)] \qquad (7)$$

The LL(H_0) refers to the *log-likelihood* value of the estimation using the Cobb-Douglas function, and the LL(H_1) refers to the *log-likelihood* value of estimating the frontier using the Translog function. If LR is greater than the value in the Kodde & Palm (1986) table, one rejects

[3] As discussed, for example, in Affonso and Aubyn (2005)

H_0, and if the LR value is inferior toe the critical value of the statistic in the Kodde & Palm (1986) table, one does not reject H_0 and the Cobb-Douglas functional form is assumed to be the more appropriate form for the model analyzed. (FERREIRA e ARAÚJO, 2013).

However, for this work, the functionality test will not be performed, since two frontiers of production will be estimated: a Cobb-Douglas and a Translog function. For a Translog-type function to be reduced to a Cobb-Douglas function, it is only necessary to impose constant returns of scale to the production function.

3.2.1.2 Absence of technical progress test

The Maximum Likelihood Ratio Test described in the previous subsection is performed to verify the lack of technical progress. In this case it is considered whether the coefficients corresponding to the variables related to time (trend) in the production function are equal to zero or not, that is, one tests the null hypothesis that the coefficient referring to time is equal to zero, characterizing the function without the influence of technological progress, against the alternative hypothesis of the function being estimated considering the influence of the trend term (time). The hypotheses are:

H_0: Coefficients related to time = 0

H_1: Complete production function

If the ML value exceeds the critical value in the Kodde & Palm (1986) table, one rejects H_0 and the influence of technical progress in the function is considered.

4 RESULTS

This session presents the results of stochastic frontier estimates to verify the efficiency of the Family Health Program in health indicators in vulnerable municipalities in the Northeast region.

Table 2 presents the results of the tests applied to verify the Cobb-Douglas functional form when compared to the translog model. The likelihood ratio proves which of the two functions has the best functional form for the model, *i.e.*, one tests the hypothesis in which all the second order coefficients, as well as the coefficients of the cross products of the function, are equal to zero.

It can be observed that, as the value of λ (-23,34) is inferior to the critical value of the statistitc in the Kodde and Palm (1986), 39,40, then it cannot be rejected. It can be assumed that the Cobb-Douglas functional form is the most appropriate one for the present analysis. Once the functional form is chosen, the lack of technical progress was then tested. As already described, the model is estimated in its functional form and in the absence of technical progress (TP). As can be seen in Table 3, the value of the statistic λ is less than the critical value of the Kodde and Palm (1986) table. Thus, it is not rejected, and the Cobb-Douglas function without technical progress is chosen as the most appropriate model to be estimated.

Table 2 - Likelihood ratio test of the parameters of the education frontier of production

Test	**Null hypothesis**	**Value of λ**	**Critical Value**	**Decision (5% level)**
Functional Form	Ho: Cobb-Douglas	-23.34	39.40	Reject Ho
Absence of TP	Ho: beta referring to time = 0	-4,23	2.56	Not reject Ho

Source: Research data. Prepared by the authors.

As discussed previously, the results of the hypothesis tests indicated as the most appropriate model the Cobb-Douglas production function without technical progress. The model was estimated with the variables in logarithm, in order to obtain the value of the coefficients be in terms of elasticities.

Table 3 presents the results of the stochastic frontier estimation for total mortality rate in northeastern Brazil, with a Cobb-Douglas functional form, with and without technical progress. The last row of the table presents Moran's global I test, indicating the non-existence of heteroscedasticity. Thus, it does not need to use a spatial stochastic frontier model. All variables used in the model were statistically significant and showed negative signs, indicating that all variables used in the model have an inverse relationship with the total mortality rate.

The Consultas variable showed a coefficient equal to -0.295, where a 1% increase in the number of consultations performed by the PSF reduces the total mortality rate by 0.13%, while the variable Equipe PSF showed a coefficient equal to -1.1298. Therefore, a 1% increase in the number of PSF professionals causes a reduction in the total mortality rate by 1.13%. The results show that the variables linked to the PSF proved to be relevant in reducing the total mortality rate in the most vulnerable municipalities in the Northeast region.

The GDP per capita variable was also significant. The coefficient equal to -0.1510 indicates that an increase of 1% in GDP per capita causes a reduction in the total mortality rate by 0.15%. Regarding the variable PMM, it shows that the Mais Médicos Program (PMM) had a positive impact on the reduction of the total mortality rate. That is, the more municipalities that adhere to the PMM, the lower the total mortality rate.

Table 3: Results of the Stochastic Frontier in taxa de mortalidade total– 2015.

Variables	**Coefficient**	**Standard Deviation**	**P>|z|**
LnConsultas	-0,1295	0,0240	0,000
LnEquipePSF	-1,1298	0,0219	0,000
LnPIBpc	-0,1510	0,0196	0,000
LnPMM	-0,0376	0.0141	0,006
Constant	3,3072	0,1935	0,000
$\ln \sigma_v^2$	-2,2741	0,1862	0,000
$\ln \sigma_u^2$	1,2485	0,6526	0,056
σ^2	0,2741	0,0628	
λ	0,6725	0,2313	
σ_u^2	0,0105	0,0068	
σ_v^2	0,0030	0,0002	
Log likelihood = -299,62	**Wald= 159,8**	**Prob = 0,0000**	**Number of observations: 324**
I Global of Moran	**0,1031**	**P- Valor=0,2452**	

Source: Research Data. Prepared by the authors.

Table 4 presents the results of the stochastic frontier model for the infant mortality rate. As for the total mortality rate, Moran I Global Test showed the absence of heteroscedasticity. The variable Consultas presented a coefficient equal to -0.2328, where a 1% increase in the number of consultations in the PSF causes a reduction in the infant mortality rate by 0.23%. The variable Equipe PSF, with a coefficient equal to -0.9544, in which a 1% increase in the size of the PSF team causes a 0.95% reduction in the infant mortality rate. The results, both for the total mortality rate and for the infant mortality rate, showed that the Family Health Program had a positive impact on reducing mortality rates in the most vulnerable municipalities in the Northeast region, corroborating the studies by Santos et al (2019), Macinko et al (2006), Santos and Jacinto (2017) and Roncalli and Lima (2006).

The GDP per capita was also significant, with the coefficient equal to -0.1982, where a 1% increase in GDP per capita causes a reduction of 0.19% in the infant mortality rate. The variable referring to the Mais Médicos Program (PMM) was also significant, being efficient in reducing infant mortality.

Table 4: Results of the Stochastic Frontier in infant mortality rate – 2015.

Variables	**Coefficient**	**Standard Deviation**	**P>|z|**
LnConsultas	-0,2328	0,0327	0,000
LnEquipePSF	-0,9544	0,0288	0,000
LnPIBpc	-0,1982	0,0438	0,000
LnPMM	-0,1442	0.0334	0,000
Constant	1,5616	0,3233	0,000
$\ln \sigma_v^2$	-2,2741	0,1862	0,000
$\ln \sigma_u^2$	1,2485	0,6526	0,056
σ^2	0,4686	0,0644	
λ	0,8466	0,0778	
σ_u^2	0,0105	0,0068	
σ_v^2	0,0030	0,0002	
Log likelihood = -842,02	**Wald= 159,8**	**Prob = 0,0000**	**Number of observations: 324**
I Global of Moran	**0,0946**	**P-value=0,3732**	

Source: Research Data. Prepared by the authors.

5 CONCLUSIONS

This study aimed to analyze the technical efficiency of the Family Health Program (PSF) in terms of health indicators in the most vulnerable municipalities in the Northeast region. For this, a stochastic frontier model was used, where there were no studies with this technique for the region.

The results obtained showed that, for the total mortality rate, the variables Consultas and Equipe PSF proved to be efficient in reducing mortality; as well as GDP per capita and the presence of the Mais Médicos Program (PMM) in the region. Regarding the infant mortality rate, the results were similar to the total mortality rate. The variables Consultas, Equipe PSF, GDP per capita and PMM were efficient in reducing infant mortality, with the number of consultations being more efficient in reducing intanfil mortality, while the number of professionals of PSF in reducing total mortality.

The GDP per capita variable proved to be more efficient in reducing infant mortality. This result can be explained by the fact that the selected municipalities have a strong concentration of poverty.

Thus, any increase in income provides improvements in the quality of life. It is expected that new studies will advance in this theme, including new evaluation techniques, as well as more recent data that can be made available, seeking to update the information. These studies are relevant insofar as the importance of the PSF in health policies in the country is presented, especially in regions (municipalities), which are more vulnerable.

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