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Abstract

The purpose of this paper was to study the productivity where renewable energy resources and non-renewable resources for generating electricity in power plants connected to the national grid of Nicaragua were used. This article analyzed the total factor productivity of Bioeconomy for the generation of electricity from plants using sugarcane bagasse (biomass) as a renewable resource and petroleum. The data envelopment analysis (DEA) and the Malmquist index were used to measure the total factor productivity of power generation utilities connected to the national grid of Nicaragua. The results obtained by comparing sugar mills connected to the SIN was that Monte Rosa mill has a higher rate of increase in productivity due to the change of total factor productivity and when comparing thermal plants that employ petroleum products in power generation, the more efficient were ALBANISA, GECSA and TIPITAPA POWER; but when comparing thermal plants and some using renewable energy San Antonio sugar mill and ALBANISA were more efficient.

JEL Classification: O14, Q43

Keywords: Productivity, Malmquist index, Biomass, Bio Economy, Oil fuel, Energy

1. Introduction

Electrical energy is produced and consumed in Nicaragua from a matrix that uses renewable energy including biomass (sugarcane bagasse), with small percentage in relation to the inputs of the thermal plants. Thermal plants that operate based on petroleum account for 60% of the installed capacity, the hydro11%, the geothermal 4.1%, the wind power 7.12%, the biomass of the sugar cane 11.79% and the isolated systems 1.2% (Nicaraguan Institute of energy, 2012).

Moreover, the process of generating electrical energy using thermal generation systems based on fossil fuels causes negative environmental impacts with heat and greenhouse gases emissions produced by the combustion of oil (CONNUE, 2009). Indeed, the negative environmental impacts come from the combustion of petroleum used to generate electricity in thermal power plants, so that, the pollutants emitted with the exception of CO_2, fall to the ground surface. As evidence of the negative effects of the use of fossil fuels in power generation, we can refer to the case of air pollution receiving direct emissions as dust particles and gaseous pollutants, and depending on the fuel used to generate power plant (type, composition and calorific value) and combustion technology, the gases can take different amounts of pollutants such as nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), unburned hydrocarbons (HC), particulate matter dust, heavy metals and organic compounds (Laguna, 2007).

Similarly, the use of fossil fuels in generating electricity emits dust particles and gaseous pollutants and also contaminates with atmospheric transformation products such as NO_2 and nitrate emissions that return to earth through precipitation and dry deposition constituting a pollution load to the water and soil that can harm vegetation and fauna (Estrucplan, 2012). Therefore, efforts are needed to encourage the implementation of new plants planned based on renewable energy to transform the energy matrix that is still dependent on fossil fuels to avoid degradation of the natural environment.

The purpose of this paper is to study the productivity of using renewable and non-renewable energy resources, as petroleum, for generating electricity in power plants connected to the national grid of Nicaragua. This article is organized into five sections. The introductory section presents the environmental problems of the use of fossil fuels in power generation. The second section is a review of literature that constitutes the conceptual framework of the methodology, based on data envelope analysis;in the third section it is presented the methodology used for data envelope analysis. The fourth section reports the data used in researching and in the fifth section are presented the research results and finally the conclusions.

2. Literature Review

2.1Basic Literature

According to Koopmans (1951) production function represents the output of the mix of factors of production according to a technological process of transformation, in which shall be considered different combinations of technical factors. Also, the production function can be understood as a series of factors of production and production techniques that can be managed to select efficient combinations in order to get the best results. Meanwhile, Farrel (1957) considered the importance of knowing how an industry can increase its production output, by simply increasing its efficiency. Thus, he proposes to analyze the productivity of a production unit in terms of its production function compared to the efficient production frontier; this efficient production function means that the technical efficiency of a production unit is compared to other units according to which the frontier function is estimated.

Coelli (2008) refers that the efficiency of a production unit can be divided into two components: technical efficiency that reflects the ability of the unit to obtain maximum production output given an input quantity and the allocation efficiency that reflects the ability to use the inputs in optimal proportions given a fixed price; these two efficiencies are combined to provide a measure of total economic efficiency. Similarly, Zuniga (2010) refers that the frontier variable means the limit of a function, and that it would represent a production function maximization (maximum output) given a set of inputs, or in a cost function, it would represent a cost function minimization (minimum cost); given the prices and outputs, in a profit function, it represents the maximum benefit. Also, a frontier function represents the best running production unit, which in turn is a reflection of the technology that is being implemented in it. The frontier function represents the best technology practice, serving it to compare the efficiency of other production units in the sector under analysis.

Meanwhile, the stochastic production frontiers Cobb-Douglas are used to obtain the conditional demand functions that minimize the cost of production and can be used to calculate the efficiency in the use of energy inputs (Armanda, Scarpellini, and Feijoo, 2003). The inefficiency can be measure in a relative sense as the deviation from the best results achieved by companies in a specific sector; thus, the analysis results in a production frontier with the intention of representing the efficient behavior of a production unit and this involves using a direct inputs, usually labor, capital and raw materials, with the maximum output that can be obtained, given the state of technology (Armanda et al., 2003; Farrell, 1957).

Moreover, productivity is regularly referred to technological changes. By contrast, the efficiency is explained when in a production unit the procedures are implemented to improve education and training to ensure that manpower produces more efficiently. Thus, productive growth can be achieved through technological progress or improvement in the efficiency of manpower.

Similarly, according to Leal (2012) in economics, the possibility production frontier (PPF) reflects the options and the need to choose between them, adjusted to our study, we can see this in the case of the Bio Economy. To produce more of one of the goods (in our study electricity is considered) means reducing energy production in the sugar mill or in the Thermal Plant, and vice versa. So that, the points outside the PPF Bio Economy curve are called "Impossible Bio Economy region FPP". Since given a number of fossil or biomass resources (i.e., if they are fully and efficiently employed and does not occur an increase of these thereof) you cannot increased the energy production of a particular power plant without reducing the energy production of other. And the points within the boundary, i.e. inside, indicate that there are unemployed resources, so this area is called the "economic inefficiency". The points on the curve are in the area is called "maximum economic efficiency" see figure 1.

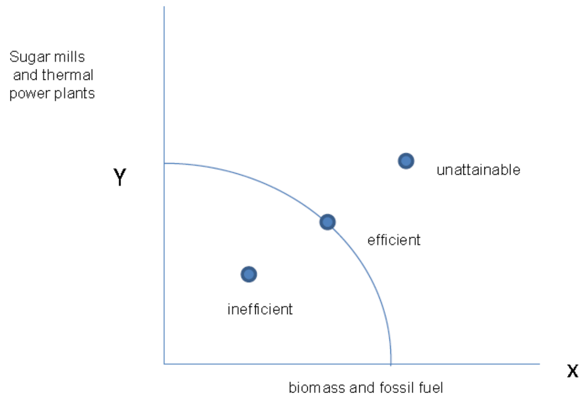

Figure 1. Production possibility frontier in the bioeconomy

To measure the productivity of energy production units there are two methods to estimate the efficiency frontiers of power plants, such as: data analysis envelopment (DEA) and stochastic frontier, these methods involve mathematical programming and econometric methods, respectively (Boris Bravo-Uretra, 2007; Zuniga,2010; Ludena, 2012; O'Donnell,2012)

The DEA Malmquist method uses panel data to estimate changes in the rates of total factor productivity (TFP) which may be: technological change, technical efficiency change and scale efficiency change. The method can be used under the Malmquist Output-oriented measure to investigate how many quantities of inputs can be proportionally reduced, with no change in the quantities produced. In addition, you can investigate how much can be proportionately increased the quantity outputs if the quantity inputsamounts are altered using the input-oriented analysis.

On the other hand, oriented output measures provide equivalent measures of technical efficiency where there are constant returns to scale. In the measurement of output-oriented efficiency, the distance AB shown in the figure 2 indicates the technical inefficiency, expressing the amount by which the outputs may be increased without additional input required. Therefore, the efficiency measure output-oriented technique is defined by the ratio:

$$ETO = \frac{OA}{OB} \quad (1)$$

If we have price information then we can plot the iso-income line DD ', and assigned define efficiency as:

$$EAO = \frac{OB}{OC} \tag{2}$$

And total economic efficiency can be represented as the product of these two measures:

$$EEO = \left(\frac{OA}{OC}\right) = \left(\frac{OA}{OB}\right) X \left(\frac{OB}{OC}\right) = ETO\ X\ EAO \tag{3}$$

These three measures are limited by values between zero and one.

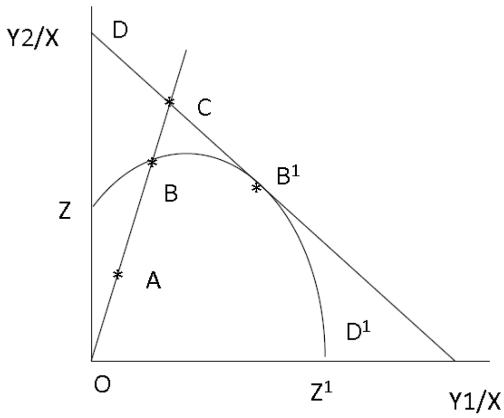

Figure 2. Technical and allocative efficiency of an oriented Output, Zúniga, 2011

2.2 Total Factor Productivity Index

Progress in total factor productivity (TFP) indicates an improvement in technology and organization of production. To measure productivity, we must focus first on the quantification of the output and the production factors used for their generation and, secondly, in the study of the relationship between the two. The approach to measuring productivity through index numbers, TFP, is defined as the ratio of an index of output (Q) with respect to an index of inputs (P) representative equation is the same equation 1.

The Malmquist index is defined using the distance function. The distance function describes a production technology multi-input, multi-output. An input distance function characterizes the production technology looking minimum proportions of input vector given an output vector; the output distance function considers proportionally expanding and maximizingthe output vector, given an input vector.

A production technology can be defined using the output:

$$P\ (X) = \{y: X\ can\ to\ produce\ y\} \tag{4}$$

The output distance function is defined in the output, P (x), as:

$$d_0(x, y) = min\left[\delta: \left(\frac{y}{\delta}\right) \epsilon\ \ P(X)\right] \tag{5}$$

The distance function, $d_0 (x, y)$ takes a value less than or equal to 1, if the output vector Y is an element of the desirable energy output, P (x). In addition, the distance function will take the value of unity if Y is located outside the desirable production set.

The DEA Malmquist index is a method of estimating frontiers functions (maximization, minimization, etc.,) using data envelope analysis (Zuniga, 2010). These distances are: a) The DEA frontier technologies to constant returns to scale run, b) the DEA frontier with constant returns to scale technologies for the current period, c) DEA frontier technologies constant returns to scale to the next period, and d) the DEA frontier technologies of diminishing returns to scale.

2.3 The Model of Constant Returns to Scale (REC)

The model considers that there is data on K inputs and M outputs for each N production units (PU) for the *i*th PU which are represented by the vector x_1 and y_1, respectively. The input matrix K x N, X, and the product matrix M x N, Y, represents the data for all output units. DEA's purpose is to build a surround border on nonparametric data observed as those under production frontier.

The best way to introduce DEA is by way of reasons. For each unit of production the producers would like to get the reason of all products on all inputs, as u' yi / v' xi, where u is an M x 1 vector of weights output and v is a vector weights inputs. To select the optimal weights we specify a mathematical programming problem:

$$Max\ uv\ \left(\frac{u'y_i}{u'x'}\right)$$

$$sa\ \left(\frac{u'y_i}{u'x'}\right) \leq 1, j = 1,2 \ldots . N$$

$$u, v\ \geq 0$$

$$(LP1)$$

It involves finding values of u and v, such that the measure of efficiency of the ith maximized farm, subject to the constraint that all efficiency measures must be less or equal to one. One problem with the development of this particular reason is that it has infinite number of solutions (Coelli, 1996), to avoid this restriction can pose v 'xi = 1, which provides:

$$max_{uv}\,(\mu\ yi)$$

$$sa\ \ v'\,xi\ \leq 0, j = 1,2 \ldots N$$

$$\mu, v\ \geq 0$$

$$(LP2)$$

This reflects the mathematical transformation procedure known as the multiplier of form linear programming problem. Using linear programming duality one can derive an equivalent surrounding form of this problem (Coelli: 1996).

$$min_{xy} \quad \theta$$

$$sa \quad -y_i + \lambda \geq 0$$

$$\theta x_i - \chi \geq 0$$

$$\lambda \geq 0$$

$$(LP3)$$

Where θ is a scalar and λ is a constant N x 1 vector. This form of involvement implies fewer restrictions than the multiplier form (K + M <N +1); hence, these is usually the preferred solution. The value of θ obtained will be the measure of efficiency for the ith production unit under the condition $\theta \leq 1$, with a value of 1 indicating a point on the frontier and consequently the technologically efficient production unit, according to the definition of Farrell (1957). The linear programming problem must be solved N times, once for each production unit in the sample. A value of θ is then obtained for energy production unit or power plant.

Working with a panel data, DEA can be used as a form of linear programming (input or output oriented) Malmquist index of TFP (Total input) to measure productivity change, and to decompose this productivity change in technology and technical efficiency change.

Färe et al (1994) specified an output based on the rate of change of Malmquist productivity as:

$$m(y_{t+1}, X_{t+1}, Y_t, X_t) = \sqrt{\left[\frac{d_0^t(X_{t+1}, Y_{t+1})}{d_0^t(X_t, Y_t)} \text{ X } \frac{d_0^{t+1}(X_{t+1}, Y_{t+1})}{d_0^t(X_t, Y_t)}\right]} \qquad LP\ 4$$

This represents the productivity of the production at the point (X_{t+1}, Y_{t+1}) relative to the production point (X_t, Y_t). A value greater than one indicates TFP growth from period t to period t +1. This index is actually the geometric mean of two outputs based on Malmquist TFP index, an index used in period t technology and other technology period t +1. A value greater than one indicate positive TFP growth from period t to period t +1.

To calculate the linear programming we must calculate distance functions of four components which engage linear programming problems; it is assumed REC and the programming approaches are:

$$d_0^t(X_t, Y_t)^{-1} = max_{\varphi\lambda} \ \phi$$

$$sa - \phi \, Y_{it} + Y\lambda \geq 0$$

$$X_{it} - X_t \ \lambda \geq 0$$

$$\lambda \geq 0$$

$$LP5$$

$$d_0^t(X_t, Y_t)^{-1} = max_{\varphi\lambda}\ \phi$$

$$sa - \phi\ Y_{it+1}\ +\ Y\lambda \geq 0$$

$$X_{it}\ - X_t\ \ \lambda \geq 0$$

$$\lambda \geq 0$$

$$LP6$$

$$d_0^t(X_{t+1}, Y_{t+1})^{-1} = max_{\varphi\lambda}\ \phi$$

$$sa - \phi\ Y_{i,t+1}\ +\ Y\lambda \geq 0$$

$$X_{it}\ - X_t\ \ \lambda \geq 0$$

$$\lambda \geq 0$$

$$LP7$$

$$d_0^t(X_t, Y_t)^{-1} = max_{\varphi\lambda}\ \phi$$

$$sa - \phi\ Y_{it}\ +\ Y_t\lambda \geq 0$$

$$\lambda \geq 0$$

$$LP8$$

Production points are compared with different types of technologies periods, the parameter need not be θ ≥ 1, as it should be when we calculate Farrell efficiency. The point should be located under feasible production set that most probably occur in LP7 where the point of production period t 1 is compared to technology in period t. If technological progress has occurred, then a value of θ <1 is possible. Note that it is possible to occur in LP8 if the technological back has occurred, but this is less likely.

The θ and λ can take four different values approach to linear programming (LP). In addition, the four linear programming problems must be calculated for each production unit in the sample (UP). So if you take 20 PU and 2 times period should be calculated 80 LP. You must calculate three LP for each PU (to build an index changed); for T periods, calculate (3T-2) for each PU of the sample, i.e. for N production units is required to calculate NX (3T-2) linear programs.

2.4 Calculations of Scale Efficiencies

Technical efficiency can be decomposed into two components, one due to scale efficiency and the other due to ¨ pure ¨ technical efficiency. If there is a difference in specific registers of units of electricity production in terms of technical efficiency, then this indicates that the unit has inefficiency scale production. So, technical efficiency to constant returns to scale (REC) is decomposed into "pure" efficiency and scale efficiency. The scale efficiency indicates whether the production unit is operating in an area of performance of increasing or decreasing scales.

The technical efficiency (TE) can be interpreted as a relative measure of the capability of managing a given technology and is derived from improved decision making, which in turn, is related to a number of variables, such as knowledge, experience and education. While, in the analysis of technological change (TC) the effect of productivity from the adoption of new production practices is evaluated and referred to investments in research and technology (Uretra –Bravo,2007).

3. Methodology

As part of the research process, information related to the input and output components of the generation of electricity in power plants that use biomass from sugarcane bagasse as a renewable resource and fossil fuel currently operating in Nicaragua and connected to the national grid was compiled. The information collected from San Antonio and Monte Rosa mills corresponds to the input of energy cogeneration process as bagasse consumption in tons. The bagasse is burned to produce steam at high pressure; the steam is transformed into mechanical energy in turbines and then transformed into electrical energy in synchronous generators. The output data corresponds to the electricity generated in GW-hr; this energy is used in the sugar mills and part is sold to the national electricity market.

With respective to the power plants based on fossil fuels, it was documented the bunker fuel input that is used for high-pressure steam. The steam is converted into mechanical energy in the turbines, and then electrical energy is generated in Synchronous electrical generators. The output of the thermal plants based on fossil fuels is detailed in electrical energy in GW-hr; this energy is sold to the national electricity market.

After gathering the information input and output of energy in the power generation systems using biomass and petroleum, we proceeded to the analysis of productivity in the exploitation of these energy resources using the methodological tool data envelope (DEA), and Malquist index to compare productivity between different power generations plants connected to the national grid of Nicaragua.

For the analysis of the efficiency of electricity production using biomass as bagasse and petroleum the data analysis method (Data Envelopment Analysis, DEA) was used. Also, panel data were used to calculate changes in the rates of total factor productivity (TFP), technological change and technical efficiency change in efficiency scaling. For the calculation, we made use of the simulation program DEAP 2.1 that contains the algorithms of the methodological process of Malmquist method and the Output-Oriented analysis.

Data panel DEA

The data analyzed in this section were obtained from the State institutions websites such as the Energy Nicaraguan Institute (INE), the National Load Dispatch (CNDC) and the Ministry of Energy and Mines of Nicaragua (MEM). We considered three Power Generation plants cases of study of Nicaragua that are connected to the National Interconnected System (SIN).

3.1 Case # 1

The first scenario considers the comparison of the sugar mills connected to the SIN and they are the San Antonio and Monte Rosa mills. The data analyzed were:

Out puts: net generation in GW-HR was used during the study period.

Inputs: Bagasse consumption measured in 103 tons of bagasse during the study period.

Coverage: We used a time series between 2002 and 2011.

3.2 Case #2

The second scenario considered was the comparison of the thermal plants that used fossil fuel in power generation connected to the SIN, the POWER PLANTS STUDIED WERE: ALBANISA GECSA, GESARSA, CENSA, CORINTO ENERGY COMPANY, TIPITAPA POWER COMPANY, GEOSA and BRISAS. The data analyzed were:

Out puts: net generation GW-HR, during the study period

Inputs: Gallons of fuel consumption during the study period and variable cost.

Coverage: a time series between 2009 and 2011

3.2 Case #3

The third scenario considered was the Case # 3: comparison of the thermal plants and renewable energy connected to the SIN, with contracts in the electricity market, the plants under study are detailed in the following table:

Table 1. Thermal plants and renewable energy connected to the SIN, with contracts in the electricity market

Generating plant	**Production Unit**	**Fuel Type**
CENSA	Production Unit # 1	Fuel oil
Corinto Energy Company	Production Unit # 2	Fuel oil
Tipitapa Power Company	Production Unit # 3	Fuel oil

GEOSA	Production Unit # 4	Fuel oil
San Antonio	Production Unit # 5	Biomass Bagasse
Monte Rosa	Production Unit # 6	Biomass Bagasse
Polaris San Jacinto	Production Unit # 7	Geothermic
Albanisa	Production Unit # 8	Fuel oil

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The data analyzed were:

Out puts: net generation GW-HR, during the study period

Inputs: Capital cost of each plant.

Coverage: a time series between 2009 and 201.

4. Results and Discussion

The main purpose of this article is the analysis of total factor productivity and technical efficiency of the bio economy in power generation plants connected to the national grid, comparing the productivity of using renewable energy resources such as biomass with the use of petroleum in power generation. So, it is intended to provide a comprehensive assessment of the resources used to generate electricity and that the study results can be considered for making decisions about what kind of energy sources foster for the energy matrix change in Nicaragua that is still dependent on fossil fuels.

We studied three cases, The first was to compare the Bio Economy of total factor productivity with the use of biomass in electricity generation, the second case was to assess the productivity of the use of petroleum in the power generation and the latter case was intended to compare the productivity of the use of renewable and nonrenewable energy together to generate electric power.

In the first case of study the comparison of the Bio Economy of total factor productivity betweenMonte Rosa and San Antonio mills yielded the results shown in table 2:

Table 2. Average growth rate of total factor productivity, technical efficiency, and technology of the San Antonio and Monte Rosa mills, during the period 2002-2011

Production Plant	effch	Techch	pech	Sech	Tfpch
San Antonio sugar mill	0.958	0.940	0.979	0.979	0.9
Monte Rosa sugar mill	1.188	0.940	1.138	1.044	1.116
Mean	1.067	0.940	1.055	1.011	1.002
Effch: technical efficiency change, techch: Technology change, pech pure efficiency, tfpch total factor productivity change.					

In geometric mean the annual growth rate of total factor productivity during the study period for both sugar mills was 0.002%, this low growth rate is reasonable in our country where the Bio Economy is not known and applied to production processes as an epistemological alternative to fossil fuel. The TFP in the Bio Economy is mainly explained by the rate of growth of changes in technical efficiency rather than technology (bio technology, bagasse and biomass) with the result of 0.067%.In turn, we can assess that this efficiency is due the growth rate of 0.55% of the pure efficiency, indicating the capacity and technical assistance of the workers in the process of bio economy and likewise it is shown an economy of scale of 0.01% in the rate of growth of technical efficiency scale.

The sugar mill with the highest rate of growth of total factor productivity is Monte Rosa. This sugar mill presented an index of 1,116, equivalent to 11.6% increase in productivity growth rate, which is due to the change in technical efficiency of 18% interannual, compared to 0.9, which represents a 10% reduction of total factor productivity of San Antonio. However, the highest rate of productivity of Monte Rosa is not due to technological change. The change in technology (bagasse as biomass) is based on the development of the activities of electricity generation using bagasse as biomass, and since both mills have the same rate of technological change (bio technology) throughout the study period, then, the highest rate of productivity is based on training of the workforce of Monte Rosa expressed in an index of 1,188, or an increase of 18.8% equivalent, technical efficiency compared to0.958 of the San Antonio mill, which has a deficit of 4.2%.

The Increase in technical efficiency for Monte Rosa mill is explained by a greater change in pure efficiency (1,138, 13.8% increase) and the efficiency in the scale of power generation (1,044, 4.4% increase). The pure efficiency change represents the difference between the change in efficiency and technology change; in our case is the difference between the Bio technology and the ability of workers, as was explained before both mills have the same characteristic Bio Technology (bagasse as biomass), with the difference that the Monte Rosa mill has developed higher performance in labor. Therefore, the change in efficiency can be explained by technical scale efficiency by the fact that on average the percentage of growth of the electric power generation is greater Monte Rosa mill with a 0.44% decrease compared to the 0.021% of San Antonio mill.

Summarizing, we can assess that during the study period the Bio Economy had a low growth, highlighting the Monte Rosa mill.In both mills is clear that this growth rate is not explained by the bio technology used, but rather by technical efficiency. It implies that scientifically, it should be reviewed the bio technological production processes in order to increase more rapidly the growth rate.

In case 2 a comparison of the thermal power plants that use petroleum in power generation connected to the SIN is made using the DEAP program and the results are shown below:

Table 3. Mean of total factor productivity, technical efficiency and technology of thermal INS employing oil in electricity generation during 2009-2011

Thermal Plants Generation	effch	techch	Pech	sech	tfpch
ALBANISA	1.034	0.992	1.000	1.034	1.026
GECSA	1.031	0.988	1.029	1.002	1.019
TIPITAPA POWER COMPANY	1.012	0.994	1.000	1.012	1.006
GESARSA	0.987	0.988	1.000	0.987	0.976
CENSA	0.979	0.989	0.979	1.000	0.969
Corinto Energy Company	1.000	0.930	1.000	1.000	0.930
GEOSA	0.854	0.950	0.854	1.000	0.811
Mean	0.984	0.976	0.979	1.005	0.960
Effch: technical efficiency change, techch: Technology change, pech pure efficiency, tfpch total factor productivity change.					

In geometric mean during the study period it is noted a decline on the pace of growth of total factor productivity (0.04%). However it shows an improvement for thermal power plant ALBANISA, GECSA and TIPITAPA POWER COMPANY.The results show that the plant that has the highest rate of total factor productivity with a 2.6% increase in its rate of growth was ALBANISA followed by GECSA plants with 1.9% and TIPITAPA POWER COMPANY with 0.6%. The highest rate of change in total factor productivity of ALBANISA, TIPITAPA POWER COMPANY and GECSA is not explained with technological change in fossil fuel use, because all plants studied have virtually the same deficit (worsen) in increasing technological change, on the contrary, the highest rate of total factor productivity of these plants is due to the change in technical efficiency, that is, in the training of human talent working in the plants.

So, for example, ALBANISA exhibits a change in technical efficiency of 3.4% which is explained in increasing scale efficiency of 3.4%, and not pure efficiency growth. Similarly, GECSA and TIPITAPA POWER COMPANY present changes in the technical efficiency of 3.1% and 1.02%, an increase of 2.9% pure efficiency for GECSA and without increased to TIPITAPA POWER COMPANY. In the scale efficiency GECSA increased 2 % and 1.2% for TIPITAPA POWER COMPANY. Therefore, the increase of productivity change factors of the power plants ALBANISA, GECSA and TIPITAPA POWER COMPANY is explained by the technology management capacity, improved decision making, increased knowledge, and experience and training of the personnel.

In summary, we note that the total factor productivity recorded geometric mean deterioration in the study period. However, ALBANISA GECSA and TIPITAPA POWER COMPANY were the only ones that recorded a growth rate of between 2.6% and 0.6%.

For the Case 3 a comparison was made between the thermal power plants using fossil fuel and renewable energy connected to the SIN, with contracts in the electricity market. The utilities under study were: CORINTO ENERGY COMPANY, TIPITAPA POWER COMPANY, GEOSA, SAN ANTONIO SUGAR MILL, MONTE ROSA SUGAR MILL, POLARIS SAN JACINTO POLARIS and ALBANISA

Table 4. Mean of total factor productivity using petroleum and renewable energy sources in electricity generation during the period 2009-2011

Power plant	effch	techch	pech	sech	tfpch
CORINTO ENERGY COMPANY	2.322	0.454	0.849	2.737	1.063
TIPITAPA POWER COMPANY	2.198	0.458	0.838	2.624	1.006
SAN ANTONIO	2.377	0.458	0.963	2.468	1.088
POLARIS SAN JACINTO	2.117	0.458	0.822	2.574	0.968
CENSA	1.935	0.458	1.131	1.711	0.885
MONTE ROSA	1.935	0.458	1.087	1.508	0.750
GEOSA	1.000	0.548	1.000	1.000	0.458
ALBANISA	2.607	0.458	1.000	2.607	1.193

Effch: technical efficiency change, techch: Technology change, pech pure efficiency, tfpch total factor productivity change.

The results of the comparison of power plants based on fossil fuel and plants using renewable sources show that the power plants with increase in total factor productivity were ALBANISA with 19.3%, CORINTO ENERGY COMPANY with 6.3% and TIPITAPA POWER COMPANY with 0.6%. About the power plants using renewable energy sources studied, highlights San Antonio sugar mill with 8.8%. The increased rate of total factor productivity of the plants specified above is explained by the increase of technological change and in turn for change in the efficiencies of scale, thus in the way of participation in the electricity market in Nicaragua.

Therefore, the increased productivity of the POWER plants ALBANISA, CORINTO ENERGY COMPANY, TIPITAPA POWER COMPANY and SAN ANTONIO SUGAR Mill is due to high technology management capabilities, improved decision making, and greater investment in training to acquire the knowledge that make them more productive. Similarly, the increase of technological change (TC) that affects productivity growth is explained in adopting new production practices and investments in research and technology. Consequently, power plants based on fossil fuel and renewable resources of energy analyzed and that resulted in low rates of productivity must take action to improve the training of human resources in their companies and improve managing the technology used in the generation of electricity.

The table 5 summarizes the results of the main estimates. The Bio Economy compared to conventional power generation was more representative highlighting the Monte Rosa sugar mill in its improvement of PTF with 11.6 % in annual growth. Conventional economics using fossil fuels resulted with a lower growth rate in TFP, highlighting, ALBANISA with 2.6%; this shows the effort of the government of reconciliation and national unity for contributing to the conversion of the energy matrix. Studying the power plants by the level of investment made in their economy of scale, ALBANISA stands in conventional economics with an increase in TFP of 19.3%. Similarly the San Antonio mill highlights for their investment in the bio economy production Bio Technology energy (bagasse from sugar cane) with an increase in TFP of 8.8%, but when tested with Biotechnology presented no improvement.

These results show the need to continue improving the total factor productivity not only in terms of investment, but in improving the bio technology processes as in the case of Monte Rosa sugar mill and decrease the growth rate of total factor productivity factors in conventional economics. These results are acceptable if we compare with other authors who have investigated the total factor productivity in Conventional Economics (Boris Bravo-Urethra, 2007; Zuniga, 2010; Ludena, 2012; O'Donnell, 2012).

Likewise, it is important to appreciate that these growth rates are above the growth rate of electricity demand; therefore the Bio-technology processes should be reviewed in terms of raising at least a 4.5% interannual to meet demand with a Bio Economy environmentally friendly considering the trend of exhaustion of non-renewable resource.

The author Bravo-Uretra used the DEA method to examine the impact of the various attributes in a study (i.e., estimation technique, functional form, sample size) to estimate the technical efficiency, for which a meta-regression analysis of 167 studies of frontier technical efficiency in agriculture published in scientific articles was made. Notably, meta-regression analysis is a quantitative method that allows assessing the effect of methodological and other specific studies on the characteristics of published empirical estimates as an indicator of technical efficiency.

For its part, the authors Ma Chunbo et al. (2011) used data envelopment analysis (DEA), Malmquist approach to estimate the relative efficiency gains in the Chinese power sector and identify the significant factors affecting the efficiency changes before and after the last reform of China's power industry in 2002. Furthermore, these authors reported that frontier methods such as data envelopment analysis (DEA) and stochastic frontier analysis (SFA) can measure productivity and compare several power plants with respect to more efficient utilities and also identified sources of inefficiency.

In this sense, the author Ludena (2012) analyzed the factor of productivity and growth in agriculture and its sub-sectors in Latin America and the Caribbean. To estimate productivity growth Ludena used Malmquist index and Data Envelopment Analysis (DEA). The DEA analysis was used for the construction of a frontier for each country and year in a sample, using the model of constant returns to scale. Also, O'Donnell (2012) used the DEA to make inferences about the returns to scale and measures the change in total factor productivity TFP and efficiency in U.S. agriculture:the results showed that the main drivers of change in agricultural productivity in California have been technical advances and improvements in scale efficiency.

The results of this study agree to apply the methodology that the author Zuniga (2013) proposed to measure the total factor productivity of Bio Economy using Malmquist index methods. The author Zúniga quoting Trigo (2011) defines Bio Economy as new ways of linking natural resources to the processing of goods and services through increasing knowledge intensity as the common denominator of new value chains. Zuniga used the efficiency measure oriented in biofuels to construct an efficiency frontier based on the concept of the Malmquist index. Zúniga examined productivity growth of the Bio Economy in 7 countries during the period 1980-2007, finding an annual growth of productivity growth of the Bio Economy of 1.1 percent, with change bio economy efficiency (or recovery bio economy) provided 0.03 percent per year and Bio Economy technical change (frontier shift or bioethanol) yielding 0.09%. In terms of country performance, the most extraordinary performance was published by Belize, with an average annual growth of 4 percent during the study period and other countries with a strong performance are average in Guatemala and Nicaragua.

According to Trigo (2011) the bio economy relates with the conception to move economies based on petroleum and petroleum products to biofuels and energy sources sustainable, environmentally friendly and with greater availability. However, it is noted that in the immediate future, biotechnology will coexist with hybrid technologies in a gradual process of change of current energy-intensive technologies to energy-efficient alternatives, with increased productivity and at the same time generating benefits in terms of natural resource management. Meanwhile, Mohammadian (2005) conceived the Bio Economy as the science that determines the threshold of socioeconomic activity to use the biological system without destroying the conditions necessary for regeneration and therefore seek sustainability. Finally, Blaschek (2008) notes that the economy, and in particular oil prices and environmental sustainability are pushing for the use of alternative feedstock materials such as biomass; it is expected that biomass could be satisfy between 25-50 % of global energy demand for the XXI century. For this reason, we compared the efficiency of the power plant based on fossil fuels with those using biomass knowing that they will operate for many years on with the purpose of promote the gradual substitution of fossil fuel with renewable energy resources.

Finally, based on the results discussed in this article is recommended to improve the overall productivity of the factors in improving power generation processes of Bio technology, and that power plants based on fossil fuels and renewable resources for generating electricity must take action to improve the management of bio technology used in power generation and thus achieve meet demand with a Bio Economy alternative.

Table 5. Comparison Chart Conventional Bio Economy and Economy in increasing total factor productivity in the use of renewable energy resources and nonrenewable (Bio Technology), during the period 2009-2011

Study Case	Energetic removable Biomass	Energetic derived from non-renewable petroleum	TFP[1]	Demand growing[2]
	Bio Economy	Conventional Economy	Geometric Mean	
Study Case # 1: Mills connected to the SIN	Monte Rosa mill		11.6%	4.5%
	Both mean mill		0.2%	

[1]Inter annual Growth rate in geometric mean

[2] According Indicative generating,PlanPeriod sector power from 2005 to 2016. National Commission Energia.2005

Study Case	Energetic removable Biomass	Energetic derived from non-renewable petroleum	TFP[1]	Demand growing[2]
	Bio Economy	Conventional Economy	Geometric Mean	
Study Case # 2: Thermic Plant		ALBANISA	2.6%	
		GECSA	1.9%	
		TIPITAPA POWER	0.6%	
		Mean of the plants studied	Deficit 4%	
Sud Case # 3: comparación de plantas térmicas y de energía Renovable	San Antonio Mill		8.8%	
		ALBANISA	19.3%	
		ENERGETIC CORINTO	6.3%	
		TIPITAPA POWER	0.6%	

Social Impact

We assume that the average growth of the technology used in the study period with records below 4.5% in the rate of population growth has a negative impact socially and economically because it involves not meet the demand for this type of service.

The production units used Bio Economy identifies the Monte Rosa and San Antonio mils, with annual growth rates above average population growth rate, therefore these companies reported a positive social and economic impact.

Companies that used conventional economics to identify the companies studied in case # 2 is below the population growth rates therefore recorded a negative impact. However in the case of group companies # 3 only Tipitapa Power Company registration no rate of population growth above the rate of population growth.

5. Conclusion

In this paper we studied the bio economy of power generation by measuring the total factor productivity in electrical plants which use non-renewable energy resources (fossil fuel derivates of petroleum) and renewable resources for electricity generation in Nicaragua and that are connected to the national grid of (SIN). To measure the total factor productivity of these power plants dataanalysis envelopment (DEA) and Malmquist indices were used.

We have considered three case studies: the first was to compare the total factor productivity of the sugar mills connected to the SIN. We found that the Monte Rosa sugar mill had a higher rate of increase in total factor productivity compared to the San Antonio sugar mill. The highest productivity Monte Rosa mill is based on the training of labor, expressed in a higher rate of technical efficiency; this mill has developed a higher performance in labor in the process of generating electricity.

In the second case studied, we compared thermal power plants connected to SIN and found that plants with higher rates of total factor productivity are ALBANISA, GECSA and TIPITAPA POWER COMPANY. The highest rate of change in total factor productivity of these plants is due to the change in technical efficiency based on the training of human talent working in the plants.

In the third case study, we compared thermal power plants that use petroleum in with power generation plants using renewable energy sources and found that plants with increased change in total factor productivity are ALBANISA CORINTO ENERGY COMPANY, TIPITAPA POWER, and among the plants using renewable energy sources highlighted the San Antonio sugar mill.

Also, it was determined that the increased productivity of the thermal power plants described above and in the case of San Antonio mill that used biomass to generate electricity, the increased in productivity is due to improved manageability of technology, improved decision making, and greater investment in training to acquire the knowledge that make them more productive. Moreover, the increase of technological change (TC) is explained in the adoption of new production practices and investments in research and technology.

However, when comparing the productivity increase in electricity generation by type of energy resources, renewable and non renewable, the result was in average that thermal power plants using fossil fuels have a deficit in productivity growth which is a disadvantage to make a commitment to supply the demand for electricity grows with an annual rate of over 4% (see table5). Meanwhile, the use of biomass energy resource for power generation has a low productivity rate averaged 2%, which means that the productivity can be improved using this resource to meet the annual growth in demand for electricity.

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References

Aranda, A., Scarpellini, S., & Feijoo, M. (2003). Analysis of energy efficiency of Spanish industry and potential savings (online). *Industrial Economics, 352*(4). Retrieved from: http://www.minetur.gob.es/Publicaciones/Publicacionesperiodicas/EconomiaIndustrial/RevistaEconomiaIndustrial/352/01%20ALFONSO%20ARANDA.pdf

Bravo-Uretra, Boris.,Solís, Daniel., Moreira, Víctor., Maripani, José., Thian, Abdouahmane., & Rivas, Teodoro. (2007). Technical efficiency in farming: a Meta regression analysis. *Journal of productivity Analysis, 27*(1), 57-72. Retrieved from: http://download.springer.com/static/pdf/400/art%253A10.1007%252Fs11123-006-0025-3.pdf?auth66=1354728336_43f0018e785747e4ec11e608c31ecde9&ext=.pdf

Blaschek, H. (2008). What Are the Possibilities for the New Bioeconomy. Proceedings of a conference, Atlanta, Georgia. Retrieved from:

http://farmfoundation.org/news/articlefiles/378-Atlanta%20final.pdf

Coelli, T. (2008). A guide to DEAP versión 2.1: a data Envelopment Analysis computer program. CEPA Working Paper 96. Retrieved from: http://www.uq.edu.au/economics/cepa/deap.php

Centro Nacional de Despacho de Carga, CNDC. (2012). Estadisticas. Retrieved from: www.cndc.gob.ni

Ministerio de Energía y Minas. (2012). Estadisticas. Retrieved from: http://www.mem.gob.ni/index.php?s=1

National Commission for the Efficient Use of Energy of Mexico, (CONNUE). (2009). Metodologías para la cuantificación de gases de efecto invernadero y consumos energéticos evitados por el aprovechamiento sustentable de la energía. Retrieved from: http://www.conuee.gob.mx/work/files/metod_gei_cons_evit.pdf

Nicaraguan Institute of Energy, NIE. (2012). Series historicas. Retrieved from: http://www.ine.gob.ni/dge.html

Estrucplan. (2012). Environmental impacts of the power plants. Argentina. Retrieved on June 11, 2012 from: http://www.estrucplan.com.ar/producciones/entrega.asp?identrega=297

Farrel, M. (1957). The Measurement of productivity.Journal of the Royal Society, A CXX, Part3, 253-290. Retrieved from: http://www.lib.ctgu.edu.cn:8080/wxcd/qw/285.pdf

Koopmans, T. (1951). An Analysis of production as an efficient combination of activities. Retrieved from: http://cowles.econ.yale.edu/P/cm/m13/m13-03.pdf

Leal, V. (2012). Production possibility frontier and opportunity cost. Retrieved from: http://www.gh.profes.net/propuestas3.asp?id_contenido=38281&ciclo=4206&cat=bachillerato&nombre_id=Problemas%20de%20Econom%EDa%20(1%BA%20Bachillerato)

Ludena, C. (2012). Agricultural Productivity Growth, Efficiency Change and Technical Progress in Latin America and the Caribbean. Conference of the International Association of Agricultural Economists Triennial Conference, IAAE. Foz do Iguaçu, Brazil. Retrievedfrom: http://iaae.confex.com/iaae/iaae28/webprogram/Paper17483.html

Laguna, I. (2007). Power generation and the environment. Retrieved from: http://www2.ine.gob.mx/publicaciones/gacetas/367/energiamed.html#top

Ma, Chunbo., Zhao, X., Ma, Q., & Zhao, Y. (2011). China's Electricity Market Reform and Power Plants Efficiency (en línea). Working Paper 1125, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia. Retrieved from: http://ageconsearch.umn.edu/bitstream/117811/2/WP110025.pdf

Mohammadian, M. (2005). La bioeconomía: un nuevo paradigma socioeconómico para el siglo XXI. *Encuentros multidisciplinares,* 7(19), 57-70. Retrieved from: http://dialnet.unirioja.es/servlet/articulo?codigo=1114027

O'Donnell, C., (2012). Econometric estimation of distance functions and associated measures of productivity and efficiency change. Conference of the International Association of Agricultural Economists Triennial Conference, IAAE. Foz do Iguaçu, Brazil. Retrievedfrom: http://iaae.confex.com/iaae/iaae28/webprogram/Paper16885.html

Trigo E. (2011). The Bioeconomy in Latin America and the Caribbean: Towards a socioeconomic research agenda. LAC regional IAAE Inter-conference Symposium on the Bio-economy. CIAT, Cali, Colombia. Retrievedfrom: http://www.bioeconomy-alcue.org/doc/IAAE-CIAT_Concept%20Note_(2nd%20_draft_22-09-2011).pdf

Zúniga, G. Carlos A., (2011). Agricultural Economic Basic Text: Its Importance for Sustainable Local Development. Brought to you by the University of Minnesota Department of Applied Economics and the University of Minnesota Libraries with cooperation from the Agricultural and Applied Economics Association. ISBN: 978-99964-0-049-0. Intellectual property registration No OL-019-2011. Available On Line en: http://purl.umn.edu/111604Unan-León 2008.

Zúniga, Carlos. (2010). Livestock Production Systems Impact of Agricultural Production Systems in Local Sustainable Development of Nicaragua, 1998-2005: DEA Malmquist Index with Output Oriented. Retrieved from: http://ageconsearch.umn.edu/bitstream/92840/2/Analisis%20de%20productividad%20de%20sistemas%20de%20producci%C3%B3n.pdf

Zúniga González, & Carlos Alberto. (2013). Total Factor Productivity and the Bio Economy Effects. Macrothink Institute. *Journal of Agricultural Studies*, Vol. 1, No. 1. P.1-29 Received: November 13, 2012 Accepted: November 24, 2012 Published: December 18, 2012. http://dx.doi.org/10.5296/jas.v1i1.2383

Glossary

SIN: National interconnected System

MW: Power unit, Mega Watts

GW-HR: energy unit, Mega watts per hour

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Appendix.

Table 6. Data of the Case study 1: Comparison of the mills connected to the SIN

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
San Antonio sugar mill	72.99	97.36	84.19	113.6	100.42	122.38	98.25	87.93	113.48	95.05
Monte Rosa sugar mill	22.8	36.74	43.73	89.83	93.93	112.9	99.37	118.07	111.08	115.47

Details of net generation in GW-HR. Source: Instituto Nicaragüense de la Energía, INE. 2012

Table 7. Input data of Mills, Bagasse consumption 103 tons of bagasse

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
San Antonio mill	174.93	269.12	494.36	585.44	563.41	640.29	574.08	562.51	682.85	587.21
Monte Rosa mill	257.15	262.55	430.56	425.35	387.53	463.08	416.13	478.85	485.1	484.02

Table 8. Output data, net generation Gw-HR

ITEM	POWER PLANT	2007	2008	2009	2010	2011
1	**ALBANISA**	99.81	159.46	512.64	503.56	734.12
2	**GECSA**	211.42	209.11	161.96	162.51	56.98
3	**GESARSA (GENERADORA SAN RAFAEL)**	4.5	11.6	8.98	2.24	3.63
4	**CENSA**	217.65	153.5	150.97	240.69	282.16
5	**EMPRESA ENERGETICA CORINTO**	550.12	518.84	511.18	508.61	527.26
6	**TIPITAPA POWER COMPANY**	409.24	392.96	390.61	376.7	392.62
7	**GEOSA**	515.98	559.6	496.43	370.66	389.66
8	**LAS BRISAS (GECSA)**	107.12	14.05	8.26	3.61	1.96

Source: InstitutoNicaraguense de la Energia

Table 9. Input data, Fuel consumtion of thermal plants 10^3 Gal

ITEM	POWER PLANT	2007	2008	2009	2010	2011
1	**ALBANISA**	7084.57	10078.85	32420.12	30494.88	44037.48
2	**GECSA**	17522.8	18303.38	14207.07	14213.48	4816.98
3	**GESARSA (GENERADORA SAN RAFAEL)**	271.05	717.76	564.94	141.53	239.89
4	**CENSA**	13837.01	8641.96	8813.98	14963.8	17593.77
5	**EMPRESA ENERGETICA CORINTO**	32845.77	30683.3	30250.99	30378.11	31521.63
6	**TIPITAPA POWER COMPANY**	25013.43	24116.69	23965.73	23076.56	23771.84
7	**GEOSA**	40967.7	44366.92	39834.54	30621.27	31946.16
8	**LAS BRISAS (GECSA)**	10,568.39	1,361.63	705.7	299.88	166.58

Source: InstitutoNicaraguense de la Energia