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Abstract

This study measures the impact of consumption Ozone-Depleting Substances (ODS) on the Gross Domestic Agricultural Product (GDAP) of the Central American Countries. The methodology used is a non-parametric program under Data Envelopment Analyze (DEA) with the Malmquist indices methods. The DEA methodology permits defining the technology bound or performance. It discomposes the total factor productivity (TFP) in technical efficiency change, technological change, pure technical efficiency change, and scale efficiency change. A panel data was made with the CEPAL economic and environment statistics. Both periods were used 1995-2006 and 2007-2008. The TFP index showed that the performance decreased to 15.4 % by the unit in the GDAP change mean, during the 1995-2006 periods. This effect was associated with the policy measures that were taken by your respective governments for producing less consumption ozone-depleting substances. This situation improved in the second period that was increased to 33.4 %. Costa Rica, Cuba, y Nicaragua were taken as a performance benchmarking of the Central American economy. On the other hand, the technical efficiency to variable scale return evidenced that the Central American countries were technical inefficiency to constants scale return and Nicaragua only was efficiency to variable scale return.

JEL Classification: Q51, O47.

Keywords: Malmquist DEA Index, GDAP, ODS, hydrochlorofluorocabons (HCFCs), Methyl bromide (Methyl Bromide), chlorofluorocarbons (CFCs)

Introduction

Air pollution has a direct effect on productive activities and therefore on people's quality of life. Its first manifestations were officially recognized in Rome with the regulations that covered the activities of certain treaties. Now, in the 19th and 20th centuries, with the increase in pollution in agricultural activities and industry, these effects are shown in a) The global decrease in the stratospheric ozone layer and the increase in the use of ultraviolet radiation on the surface; b) the occurrence of smog in summer over most of the world's cities, including underdeveloped countries; c) The increase in the atmosphere of the greenhouse effect (gases) and aerosols associated with climate change; d) acid rain and eutrophication of water surfaces and other natural ecosystems by atmospheric declaration; e) Exalt the levels of aerosol and photo-oxidants from biomass burning and other agricultural activities; f) The increase of fine particles in regions of industrial development and population growth with assistance to reduce visibility increasing the effects on human health; g) air pollution due to the use of transportation to regions of industrial activity; and h) the persistent appearance of semi-volatile organic compounds and heavy metals in regions far from their sources of origin.

Many of these changes in atmospheric composition have adverse effects on the health of people and ecosystems, on water supply and quality, and on crop growth. A variety of moderate measures have been introduced or considered to reduce the effects. However, the continued growth of productive activities, to improve the economy and alleviate poverty, ensures that these effects continue to be a concern of future generations.

Air pollution involves the transport of pollutants between emission sources and deposition sites, as well as the transport of chemical pollutants in the atmosphere. Not only pollutants and trace pollutants removed by atmospheric processes can be transformed into secondary pollutants; An example here is the ozone layer which results from the reaction of nitrogen oxides and hydrocarbons in the presence of sunlight. Thus, air pollution combines the complexity of meteorology with that of atmospheric chemistry and while we have a reasonably complete picture of the situation, the details on which forecasting and analysis depend are far from clear.

In figure 1 presents the consumption of substances that deplete the ozone layer (ODS) of the Central American countries: Costa Rica, Cuba, El Salvador, Guatemala, Honduras, Nicaragua and Panama, during the period 1995.2008. SAO[1] based on art. 1 of the Vienna Convention for the protection of the ozone layer and art. 1 of the Montreal Protocol on Substances that Deplete the Ozone Layer, are: hydro-chloro-fluoro-carbons (HCFCs), such as Genetron, Freon, Arcton; methyl bromide (Methylbromide), such as Bromogas, methan-sodium, telone, DAZOMET and fully halogenated chloro-fluoro-carbons (CFCs), such as Genetron, Freon, Arcton.

[1] ODS shall be understood as chemical, organic compounds, halogenated derivatives of hydrocarbons, in gaseous state, which are used as refrigerants, foaming agents, aerosol propellants, solvents, gaseous pesticides and extinguishing gases, which are chemically stable and their emissions into the atmosphere destroy the ozone layer or significantly alter it (Decree No 38, Official Gazette Volume No 347 Ministry of the Environment and Natural Resources of El Salvador, Nov. 26, 1992).

All the countries show a decreasing trend in consumption (ODS), thus Guatemala is the exception because its trend was increasing during 1995-2000, but it fell in 2001, hence a decreasing trend was observed. The countries with the highest consumption of ODS are Cuba, Guatemala, Honduras and Costa Rica. The countries with the lowest consumption of ODS are El Salvador, Panama and Nicaragua.

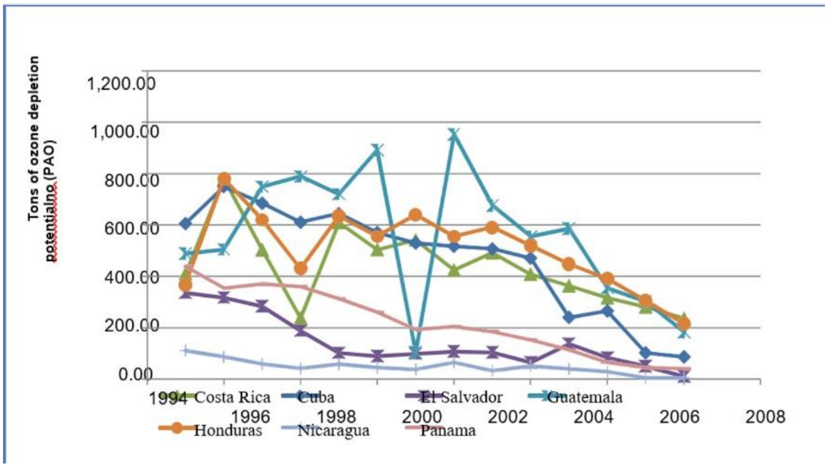


Fig. 1 Consumption of substances that deplete the ozone layer in the Central American countries: 1995-2008

Below is the schedule for the elimination of the consumption of controlled substances in force, which establishes strict deadlines for developed and underdeveloped countries (PNUMA: 2005). According to the results of Fig. 1, we could affirm that the reduction is consistent with the reduction plan in developing countries. In such a way, it is important to assess whether this reduction has indeed had a positive impact on the agricultural production subsystems. It is about assessing the impact on the Central American economies.

Substance	***Percentage reduction in industrialized countries***	***Percentage reduction in developing countries***
CFC	100 % in 1996	in 1996 As of 1999, consumption must not exceed the average value from 1995 to 1997 and a 50% reduction is required in 2005, 85% in 2007 and 100% in 2010
HCFCs	0 % en 1996, 35 % en 2004, 65 % in 2010, 90 en 2015, 99.5 en 2020 y 100 % en 2030	In 2016 a reduction of 15% of the consumption of 2015 and 100% in 2040 is required.
Bromuro de Metilo	0 % en 1996, 25 % en 1999, 50 % en 2001, 70 % en 2003y 100 % en 2005.	As of 2002, consumption must not exceed the average value from 1995 to 1998 and the following is required: 20% reduction in 2005 and 100% in 2015.

Figure 2 presents the evolution of GDPA, during the period 1995-2007. We note that the lowest value is Nicaragua and the highest is Guatemala. All countries showed a growing trend despite the financial crisis originating in the E.U. The case of Cuba presented a slight downward trend in the years 2004 to 2006.

Comparing figures 1 and 2 we can conclude that when countries reduced their consumption of ODS, they increased their economic activity (PIBA). Now we still have to measure efficiency and productivity as an effect of the measures taken by the Central American governments.

This information is related to the degree of compliance with the Montreal Protocol agreements. The Central American countries assumed a progressive program to reduce the consumption of ODS during the period 1999-2010 (Official Gazette, 1995). These reduction measures were applied by the Ministries of Natural Resources and the Environment, with special regulations on the control of the consumption of (ODS) in the respective countries studied. In the case of Honduras, the measurements were taken by the technical unit of the ozone layer (SERNA, 1993).

To limit the use of (ODS), they organized a set of measures among which we can mention that a system of licenses for the import and export of ODS was introduced, with a ban on the customs authorities allowing the control of certain controlled substances. . New equipment was enabled in companies which previously used ODS in their technological processes. Recycling facilities were also provided to reduce ODS consumption. An information system for the consumption of ODS was introduced to process and analyze data on the volume imported or exported from the countries studied. The rules for permitted emissions to import and export ODS-containing products were stringent and also involved governments producing ODS and repairing, maintaining and servicing ODS-containing equipment (UNEP, 2000).

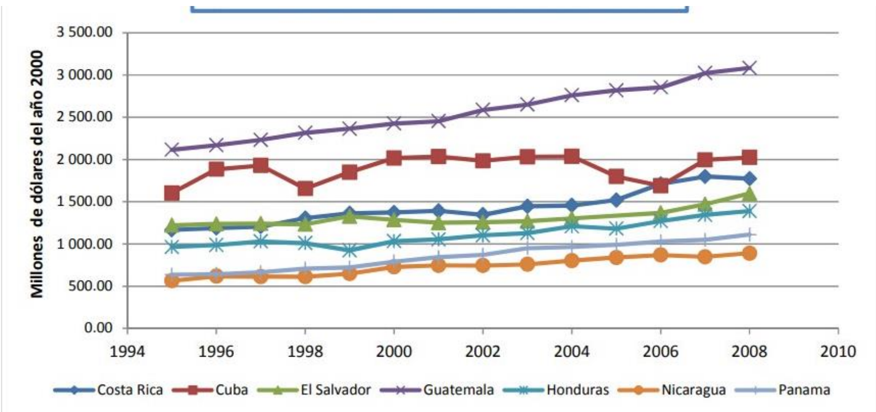


Fig. 2 Gross Domestic Agricultural Product

The study is structured with a section for the review of the literature, the data used were analyzed in the third section, the methodology in the fourth section and, in the last section we present the results and the discussion of this problem.

Literature review

The literature review is divided into two parts. The first part reviewed the SAO and in the second the methodology of the Malmquist indices.

The Montreal Protocol on the issue of substances that deplete the ozone layer is one of the most effective multilateral agreements currently in existence. Established to control the production and consumption of CEFCS and other ozone-depleting chemicals, the Protocol is an example of an agreement that places restrictions on international treaties of interest to the global environment, a feature that may become common in future treaties (Brack 1996).

The Montreal protocol regarding ODS consumption is an international deal. It was designed to protect the ozone layer by reducing the production and consumption of many substances that are studio zone-depleting letting substances. The treaty was negotiated in 1987 and entered into force on January 1, 1989. The first part of the meeting was held in Helsinki in May 1987. Since then, the document has been revised several times, London in 1990, Nairobi in 1991, Copenhagen in 1992, Bangkok in 1993, Vienna in 1995, Montreal in 1997, and Beijing in 1999. If all countries met the of the treaties, the ozone layer would recover in the year 2050. Due to the high levels of acceptance and implementation, the treaty has been considered as an example of cooperation.

The treaty focuses on substances that deplete the ozone layer. Depleting refers to the level of depletion of the ozone layer by chemical destruction. SAO are those that contain chlorine and bromide. Each group of substances has established a reduced schedule for its production and consumption until its partial elimination.

For the full member countries of the EEA, the consumption and production of ODS have fallen sharply, particularly in the first half of the 1990s. Before the Montreal Protocol was signed in 1987, ODS production in the EEA held about 516,616 ODP (i.e ozone depleting potential) tonnes. In 2006 production was lowered to 114 ODP tonnes, and in 2007 it was lowered to negative levels. Negative numbers are possible because production is defined under Article 1(5) of the Montreal Protocol as minimum production, the minimum amount destroyed, and the amount entirely used as a reserve in the manufacture of other chemicals. Also, the calculated production can be negative if the amounts destroyed and stockpiles exceed production. Consumption is defined as production plus imports minus exports, ODS consumption can be negative.

Globally, UNEP summarizes the Montreal protocol on ODS showing clear evidence of a decrease in the atmospheric load of ODS in the lower atmosphere and stratosphere, as well as some early signs of a beginning of the expected recovery of the layer. of stratospheric ozone (UNEP, 2006).

The UNEP assessment synthesis is supported by the three assessment panel reports (e.g science panel, environmental effects panel and technology and economics panel). The panels are the pillars of the ozone layer protection regime since the implementation in 1987 of the Montreal Protocol (e.g the UNEP treaty to protect the earth's ozone layer). According to the panels' conclusions, there are a number of options available to return to pre-1980 levels (the period used as a reference point for the global recovery of the ozone layer). These include: 1) accelerated phase out of hydrochlorofluorocarbons (HCFCs), and strict control of methyl bromide (Methylbromide) applications, and 2) immediate collection and destruction, in order of importance, of halogens and chlorofluorocarbons (CFCs).

There is also a relationship between ODS and climate change. According to the panel of the effects of the environment of the Scientific Assessment of the UNEP 2006 under the Montreal Protocol, ODS also influences climate change from ozone and the chemical composition responsible for its depletion, which are active gases with greenhouse effects. Yet the warming due to ODS and the cooling associated with the depletion of the ozone layer are distinctive mechanisms forcing the climate that do not simply offset one another. The panel concludes that bromide gases contribute much more to cooling than heating, while CFCs and HCFCs contribute more to heating than cooling. CFCs and HCFCs contribute only to calendar (PNUMA, 2005).

Internationally, efforts to safeguard the earth's climate (UNFCCC and its Kyoto Protocol) and the protection of the ozone layer (Montreal Protocol) can be mutually comprehensive. HCFCs damage the ozone layer although less than CFCs and contribute to global warming. They were planned as substitutes for the 2030 phase for developed countries and in 2040 for underdeveloped countries. However, concentrations of HCFCs continue to increase in the atmosphere. In 2007, the governments of developed and underdeveloped countries agreed to freeze the production of HCFCs in underdeveloped countries by 2013 and contribute to the final phase date of these chemicals for ten years in both developed and underdeveloped countries (Montreal /Nairobi, September 22, 2007). This can be seen as a historic agreement to address the risks of protecting the ozone layer and combating climate change at the same time.

In the European Union, the European commission presented a proposal to amend regulation No 2037/2000 on substance that depletes the ozone layer. The proposal removes absolute provisions and procedures, obligates rational reporting and also provides phase-out production of HCFCs from 2025 to 2020. It also introduces amendments to comply with and prevent illegal treaties or use of ODS in the European Union. In addition, the proposal highlights the current provision in the recovery and destruction of ODS contained in products and equipment. There is also a list of new substances for which the production and import volumes have to be reported. Ultimately, the proposal lowers the stock cap on methyl bromide use to guarantee and pre-ship and ensure a full phase out of such uses by 2015, while making available technology recapture.

Finally, the latest research from scientists at the German Air Space Center DLR shows the ozone layer over Antarctica was expanded in 2008 compared to 2007. The ozone layer was measured in October 2008 by the sensor from SCIAMACHY aboard ESA's ENVISAT. The size reached about 27 million square kilometers. This is approximately 6 times the territory of the European Union.

The second part of the literature review focused on the methodology to measure the impact of the effects of ODS consumption on the economic activities of the countries studied.

Regarding the methodology to analyze the impact of SAO, some authors use the input-output matrix approach as part of establishing national accounts, which was discussed in the 1930s and was first implemented in the 1940s by the United States of America. Its founder was Wassilyu Leonfief (1936), and his approach to national accounts was disaggregated, focusing on how industries trade with each other, and how inter-industries trade in influencing aggregate demand for labor and capital. an economy.

Using linear algebra and input-output analysis allows all economic activities to be related to final demand. Of course, the final demand adds the production of the sectors of the Domestic Gross Domestic Product, one of the fundamental measures of the national accounts. The Input-Output matrix can be used for the analysis of various sectors within and outside of government. The use of the Input-Output matrix is particularly important to analyze the adjustment of the structure in the industry (Miller and Blair 1985, Proops et al. 1993).

The Input-Output analysis was applied to determine the direct and indirect emission of the different sectors (Argüelles and Benavides, 2006). Modern efficiency measurement began with Farrell (1957) and Lovell (1993) who took up the work of Debreu (1951) and Koopmans (1951) to define a simple measure of the efficiency of a company (firm), which could account for multiple inputs. Farrell proposed that the efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain the maximum output from a given set of inputs (isoquant), and allocative efficiency, which reflects the ability of a firm to companies to use the inputs in optimal proportions, given the respective prices (Isocosts). The combination of both measures provides the total economic efficiency.

The oriented Input measure leads to the answer How much can the quantities in metric tons of ODS be reduced, without altering the production of GDPA?

Envelope data analysis is a nonparametric mathematical programming approach to estimate frontier. This approach was raised in the works of Boles (1966), and Afriat (1972), however it is until the works of Charnes, Cooper and Rhodes (1978) that they adopt the method of data envelopment analysis (DEA for its acronym in English). These authors proposed a model in which they had an oriented input and assumed constant returns to scale. Subsequently, other articles have considered a set of variations, such as Banker, Charnes and Cooper (1984), who proposed variable returns to scale.

The DEA methodology makes it possible to define the technological frontier, or best practices, that is, the maximum amount of PIAB possible given the consumption of ODS (Inputs), based on the considerations observed for the substances defined above. The DEA proposal combines the use of Malmquist indices of changes in productivity over time. These indices break down the growth of total factor productivity into two components: changes in technical efficiency and changes in technology, over time, thus identifying what is called "catch up" (efficiency, on the one hand, and innovation (technology) on the other (Lanteri, 2007).

The DEA methodology uses what is called, in the literature, 'distance functions', which represent the inverse of Farrell's (1957) original measurement of technical efficiency. This methodology uses only information on quantities, both of the products and the inputs used.

Malmquist indices were originally introduced in the realm of consumption theory (Malmquist, 1953). This proposal was later applied to the measurement of productivity, by Caves, Christensen and Diewert (1982), in a context of production functions, and by Fare, Grosskopf, Lindgren and Roos (1989), in a context (DEA) not parametric. Malmquist productivity indices have been applied in several studies, including: Hjalmarsson and Veiderpass (1992), Bjurek and Hjalmarsson (1995), and Grifell-Tatjé and Lovell (1995).

Data

The ECLAC databases were used in the section on statistical publications and environmental indicators, Economic Statistics. From which the data panel was built with six Central American countries: Costa Rica, Cuba, El Salvador, Guatemala, Nicaragua and Panama. Each country includes the agricultural gross domestic product (PIAB) at constant market prices for the year 2000 measured in millions of dollars. The sectors included in the PIAB are agriculture, livestock and forestry. Input data are volumes measured in tons of hydrochlorofluorocarbons (HCFCs), methyl bromide (Methylbromide), and chlorofluorocarbons (CFCs). Two periods were organized: one from 1995 to 2006, which in the case of Nicaragua implies the measures of the neoliberal governments, and the period from 2007 to 2008, which reflects the measures of the new government of reconciliation and national unity.

The technology referred to in the study indicates the measures that, according to the Vienna Convention and the Montreal Protocol, the Ministries of the Environment apply ministerial regulations in each of the countries studied to control the consumption of ODS. Our approach was justified considering that producers use ODS in production processes, as in the case of methyl bromide, which is a widely used soil disinfectant in export crops, such as cut flowers and melons. The technology represents the alternatives used by producers to not use ODS such as solarization, bio-compost, biofumigation) and other environmentally friendly measures.

Methodology

The involved data analysis (DEA) methodology uses the non-parametric method of mathematical (linear) programming. To determine the distance between the production points and the technological frontier, a version of the DEA methodology with input orientation (SAO) was used, under variable returns to scale, which involves non-parametric programming methods. This methodology makes it possible to estimate the Malmquist indices of productivity changes over time in order to determine the best technological practices (Alam and Morrison, 2000; Gonzalez, 2020; Gonzalez, 2011).

Under constant returns to scale, the efficiency changes component could be decomposed into scale efficiency changes and pure efficiency changes (efficiency changes = pure efficiency changes * scale efficiency changes). The change in pure efficiency measures the change in technical efficiency under the assumption of a technology with variable returns to scale, while the change in scale efficiency indicates the change in efficiency due to movements towards or away from the scale point. such that economies that are too small, or too large, relative to the optimal size of their industry, would be scale inefficient (Fulginiti et al. 1997, Piesse and Thirtle 1977, Gonzalez 2011).

The methodology considered in the work allows estimating the technological frontier, from the data involved in the data panel. The points on the frontier reflect the periods during which the economy uses the available resources in the most technically efficient way.

The DEA method of Malmquist indices was used in panel data, which allows calculating the decomposition of total factor productivity in (TFP), technological change, change in pure efficiency, change in efficiency at scale and technical efficiency change (Fare Grosskopf, Norris and Zhang: 1994).

The problem to be investigated is how much the quantities in tons of substances that deplete the ozone layer can be reduced without changing the quantities produced of the gross agricultural domestic product (Measures Oriented to ODS of technical efficiency).

Figure 3 illustrates the measurement of technical efficiency with input oriented to variable returns on technological changes. In our case we consider a reduction in ODS consumption represented by F(x), the countries operating at point P are inefficient because they are below their distance point or technological frontier defined by point R. The graph with the data studied can review it in the annexes, fig 4.

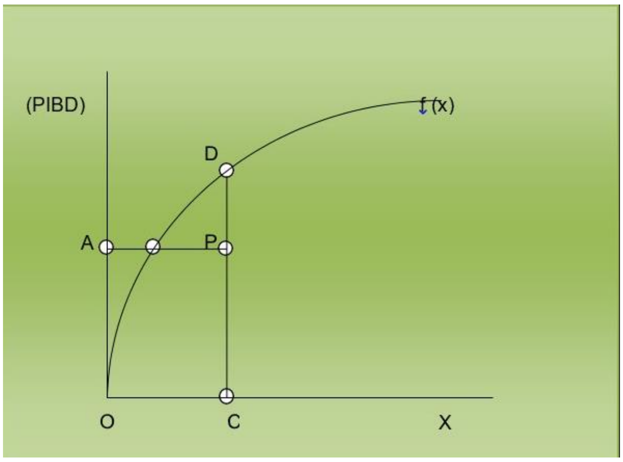


Fig. 3 Technical efficiency measurement with Input-Oriented, and returns variable to scale

The measure of technical efficiency to reduce ODS according to Farrell should be equal to AB/AP. Oriented Input will measure only if there is an equivalent measure if technical efficiency is measured at constant returns to scale, but will be unequal when increasing and decreasing returns to scale are present (Fare and Lovell: 1978). In our study, it corresponds to the second situation.

The DEA, the Malmquist index, and linear programming were used to estimate the change in GDPA productivity and decompose this change in productivity into technological change and change in technical efficiency Fare et al (1994) specified an oriented product (in our case input-oriented) of the change of the Malmquist index as in (Grosskopf. 1993):

$$m_0(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} x \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}} \qquad (1)$$

This is the PIAB productivity point (x_t+1, y_t+1) relative to the GDPA point (x_t, y_t). A value greater than 1 will indicate a positive TFP growth in period t to period t+1. Actually, this index is the geometric average of two Malmquist PTF indices. One index uses the technology for period t (ie the policy to reduce ODS consumption) and the other for the technology for period t+1. To calculate Eq. 1 we must calculate the four components of the distance functions, which involve four linear programming problems (similar to the one conducted in the calculation of the Farrel technical efficiency), that is:

$$
\begin{aligned}
&[d_0^t(x_t, y_t)]^{\frac{1}{2}} = max_{\phi,\lambda}\phi, \\
&st \qquad -\phi y_{it} + Y_t\lambda \geq 0, \\
&\qquad\quad x_{it} - X_t\lambda \geq 0, \\
&\qquad\quad \lambda \geq 0,
\end{aligned} \tag{2}
$$

Los tres problemas de PL destacados son simple variantes de esto:

$$
\begin{aligned}
&[d_0^{t+1}(x_{t+1}, y_{t+1})]^{-1} = max_{\phi,\lambda}\phi, \\
&st \qquad -\phi y_{i,t+1} + Y_{t+1}\lambda \geq 0, \\
&\qquad\quad x_{i,t+1} - X_{t+1}\lambda \geq 0, \\
&\qquad\quad \lambda \geq 0,
\end{aligned} \tag{3}
$$

$$
\begin{aligned}
&[d_0^t(x_{t+1}, y_{t+1})]^{-1} = max_{\phi,\lambda}\phi, \\
&st \qquad -\phi y_{i,t+1} + Y_t\lambda \geq 0, \\
&\qquad\quad x_{i,t+1} - X_t\lambda \geq 0, \\
&\qquad\quad \lambda \geq 0,
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
&[d_0^{t+1}(x_t, y_t)]^{-1} = max_{\phi,\lambda}\phi, \\
&st \qquad -\phi y_{it} + Y_{t+1}\lambda \geq 0, \\
&\qquad\quad x_{it} - X_{t+1}\lambda \geq 0, \\
&\qquad\quad \lambda \geq 0,
\end{aligned} \tag{5}
$$

Note that in PL's 4 and 5, where production points are compared to technologies of different times in different periods, the \$ parameter needs to be ≥ 1, as calculated in Farrell's efficiency. The point can be located below the feasible production line. This should most commonly occur in PL 4 where a production point from period t+1 is compared to the technology from period t. If technological progress has occurred, then a value of \$ < 1 is possible. Note that it could also be possible for PL 5 to occur if technical progress has occurred, but this is less likely.

These indices were estimated with the DEAP Version 2.1 program, an involved data analysis program (Coelli 1996).

Results

In this paper, measures of total factor productivity and its components were estimated for a sample of seven economies, including Costa Rica, Cuba, Guatemala, El Salvador, Honduras, Nicaragua, and Panama. The sample uses annual data, corresponding to the period 1995-2007.

In the estimations, the PIAB is considered, as a measure of the added value of the agricultural, livestock, and forestry subsectors, and as input, the tons of substances that deplete the ozone layers consumed in the production process of the PIAB are represented.

The DEA methodology, used in the work, compares the performance level of each country with the best technological practices (alternatives to non-consumption of ODS and mitigation measures to the effect of climate change), which take place during the study period. In this way, it is possible to establish a technological frontier, through the sample data, that indicates the largest amount of product attainable, with the given levels of input (orientation towards ODS). In this sense, the degree of technical inefficiency of each economy would reflect the distance between the points observed and the technological frontier. A Malmquist index value, or any of its components, less than one indicates a deterioration in performance between two periods, while a value greater than one indicates an improvement over the previous period.

The Malmquist indices allow changes in productivity to be broken down into a component of technical efficiency and another of technological progress. While the technical efficiency reflects how the economies are able to use the reduction of the ODS (inputs) available from the measures taken by the Ministries of the Environment (technology) applied in the existing production process, the technological development shows the reductions of the consumption of ODS that could be achieved, from one period to another, maintaining the same level of GDAP (Piesse and Thirtle 1997).

Malmquist productivity change indices are estimated for the averages of the indicated periods and for each country. By subtracting one of the numbers indicated in the tables, the corresponding geometric average growth rates are obtained. Table No 1 presents the Impact of ODS consumption on the breakdown of total factor productivity. Estimates for the period 1995-2006 and 2007-2008. Average annual changes by country.

In table 1, it was observed that the productivity of the economies on average presented deterioration (15%), however in the second period an improvement was shown (33%), during the first-period productivity did not experience growth during the period 1995 -2006, for no country, except Nicaragua, which remained on the technological frontier or good practices (12%), while the rest of the economies move away from this frontier. The decrease in the Malmquist productivity index, on a geometric average, represented 12% for Costa Rica, 1.2% for Cuba, 6.6% El Salvador, 16.7% for Guatemala, 45% for Honduras, 29% for Panama, in the case of Nicaragua it experienced an improvement in its good practices with 12% increase. This deterioration in the economies (performance) is explained as a negative impact (28.1%) in the change of technical efficiency to constant returns to scale, that is, in the adoption of ¨catching up¨ of the reduction of ODS in the productive processes. (Import of supplies); however, the impact of technological change was positive for each of the countries, representing 11.7%. Technological and efficiency changes reflect, respectively, innovation and catching up towards the technological frontier. The reduction in the consumption of ODS has had a negative impact on technological innovation, however, it has been positive in the assimilation of the workforce.

Nicaragua, with a value of 1,177 TFP for the first period, and Costa Rica, Cuba, and Nicaragua with values of 1,032, 80,982, and 1.05 TFP, respectively for the second period, these values represent the economies that establish the Central American technological frontier, or the best technological practices in terms of producing with environmentally friendly alternatives while maintaining reduced levels of ODS consumption, in this sense, Costa Rica, Cuba, and Nicaragua achieve positive changes in productivity, although through the change in technical efficiency they show deterioration, although it is noteworthy that in the second period only Cuba achieves a high ¨catching up¨ and Nicaragua remains at the optimal level during both periods. For technological change (Innovation), all countries present a positive change in both periods, while the "catching up" of the rest of the economies is led by the technological progress achieved by Cuba and Nicaragua. These results are in line with those found by Fare et al. (1994), when considering a sample of 17 O.E.C.D.

Table No 1 Impact of ODS consumption on the breakdown of total factor productivity. Estimates for the period 1995-2006 and 2007-2008. Average annual changes by country

	Efficiency change		Technology change		Pure efficiency change		Scale efficiency Change		Malmquist Index (TFP)	
País/Periodo	1995-2006	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008
Costa Rica	0.745	0.983	1.177	1.05	0.774	1.032	0.962	0.952	0.876	1.032
Cuba	0.84	77.119	1.177	1.05	0.873	40.491	0.962	1.905	0.988	80.982
El Salvador	0.794	0.797	1.177	1.05	0.825	0.837	0.962	0.952	0.934	0.837
Guatemala	0.708	0.254	1.177	1.05	0.736	0.267	0.962	0.952	0.833	0.267
Honduras	0.468	0.842	1.177	1.05	0.815	0.885	0.574	0.952	0.551	0.885
Nicaragua	1	1	1.177	1.05	1	1	1	1	1.177	1.05
Panamá	0.602	0.412	1.177	1.05	1.091	0.433	0.552	0.952	0.708	0.433
Promedio geometrico	0.719	1.27	1.177	1.05	0.866	1.2	0.83	1.059	0.846	1.334

Note: Values greater than 1 indicate deterioration and less than 1. To get growth rates (%), subtract 1 from the values and multiply by 100

Table 2 shows the impact of ODS consumption on the convertibility decomposition of total factor productivity. The convertibility of productivity experienced growth in 1998 (18.7), 1999 (27), 2000 (20.5), 2003 (87.7), in the rest of the years it decreased. With respect to the second period, a growth of 33.4% was observed with respect to the previous year (2007). These increases are justified by the growth of technological change 1996 (40.6), 1997 (46.5), 1998 (42.6), 2000 (46.6), 2001 (22.5), 2003 (105.5), 2005 (34.4) and 2006 (42.9), in the years 1999, 2002, and 2004 they showed decrease, on the other hand, the change in technical efficiency only in the years 1999 (69.8), and 2004 (26.8) experienced growth, the rest of the countries showed decrease. During the second period, the growth is justified both by its growth in ¨catching up¨ and ¨innovation¨.

Table 2 Impact of ODS consumption on the breakdown of total factor productivity. Estimates for the convertibility period 1995-2006 and 2007-2008. Average annual changes for all countries

Country	Efficiency Change		Technology change		Pure efficiency change		Scale efficiency change		Malmquist index (TFP)	
	1995-2006	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008	1995-2000	2007-2008
1995 / 2007										
1996 / 2008	0.607	1.27	1.406	1.05	0.762	1.2	0.797	1.059	0.853	1.334
1997 / 2009	0.399		1.465		0.592		0.674		0.584	
1998 / 2010	0.832		1.426		0.519		1.604		1.187	
1999 /2011	1.698		0.748		2.205		0.77		1.27	
2000	0.822		1.466		0.848		0.968		1.205	
2001	0.746		1.226		1.391		0.536		0.914	
2002	0.812		0.572		0.854		0.95		0.464	
2003	0.913		2.055		0.9		1.015		1.877	
2004	1.268		0.673		0.958		1.324		0.853	
2005	0.456		1.344		0.658		0.693		0.613	
2006	0.293		1.429		0.694		0.422		0.419	
Promedio geometrico	0.719	1.27	1.177	1.05	0.866	1.2	0.83	1.059	0.846	1.334

Note: Values greater than 1 indicate deterioration and less than 1. To get the growth rate (%), subtract 1 from the values and multiply by 100

Tables 3 and 4 show the estimates of the variations in technical efficiency at constant returns and variables of scale, during the period 1995-2006 and 2007-2008. We value the size of the economies of scale according to the optimal scale. We use the variable returns to scale model, which shows us technical inefficiency in all countries at constant returns to scale, except for Nicaragua, which remains efficient at variable returns to scale in both periods. All the countries presented in their economies a size below the optimal size, however during the second period we noticed improvement with the exception of Guatemala. The last column of the table informs if there was growth or decrease in the technical efficiency to reduce consumption of substances that deplete the ozone layer in relation to the distance of the point of its frontier in the technical efficiency at variable returns, in that sense Costa Rica, Cuba, El Salvador, and Honduras experienced growth with respect to the border during the first period, but not so in the second period where all the countries did not indicate growth in relation to the size of the productive units; Guatemala grew in the first period and decreased in the second, the case of Panama showed a decrease in both periods, and, finally, the case of Nicaragua did not experience change, that is, it remained at the optimal size both at constant returns to scale and at returns to sliding scale.

Table 3 DEA estimation of scale variable returns with oriented input, 1994-2007

Country	TE CER		TE VER		Scale		growth/decrease rate			
	1995-2006	2007-2008	1995-2006	2007-2008	1995-2006	2007-2008	1995-2006	2007-2008	1995-2006	2007-2008
Costa Rica	0.0002	0	0.172	0.005	0.001	0.000	0.999	1.000	IRE	DRE
Cuba	0.001	0	0.380	0.0815	0.004	0.000	0.996	1.000	IRE	DRE
El Salvador	0.0005	0	0.1843	0.006	0.003	0.000	0.997	1.000	IRE	DRE
Guatemala	0.0002	0.0005	0.1728	0.111	0.001	0.005	0.999	0.995	IRE	DRE
Honduras	0.069	0	0.630	0.0105	0.110	0.000	0.890	1.000	IRE	DRE
Nicaragua	1	1	1	1	1.000	1.000	0.000	0.000	****	****
Panamá	0.237	0.143	0.861	0.183	0.275	0.781	0.725	0.219	DRE	DRE
Promedio	0.1869	0.1634	0.4856	0.1996	0.1991	0.2551				

Note: Values greater than 1 indicate deterioration and less than 1. To get the growth rates (%), subtract 1 from the values and multiply by 100

Table 4 Impact of ODS consumption on technical efficiency. Estimates for the period 1995-2007. Average change at constant and variable returns to scale across all countries.

Years	Technical efficiency at constant returns to scale relates to technological change						Technical efficiency at returns to scale of variables (RSV)	
	t-1		t		t+1			
1995 / 2007	0	0	0.258	0.143	0.183	0.136	0.668	0.183
1996 / 2008	0.288	0.15	0.205	0.143	0.14	0	0.544	0.18
1997	0.246		0.168		0.118		0.491	
1998	0.232		0.163		0.218		0.447	
1999	0.143		0.191		0.13		0.462	
2000	0.25		0.171		0.139		0.527	
2001	0.214		0.175		0.305		0.566	
2002	0.112		0.196		0.095		0.464	
2003	0.359		0.175		0.259		0.498	
2004	0.135		0.2		0.149		0.488	
2005	0.271		0.201		0.141		0.357	
2006	0.204		0.143		0		0.315	
Promedio	0.205	0.075	0.187	0.143	0.156	0.068	0.486	0.1815

Note: Values greater than 1 indicate deterioration and less than 1. To get the growth rates (%), subtract 1 from the value and multiply by 100.

Conclusions and discussion

In this paper, the impact on the GDPA due to the consumption of ODS based on the growth of total factor productivity and its components, through panel data, is analyzed for the cases of the economy of Costa Rica, Cuba, Guatemala, Honduras, El Salvador, Nicaragua, and Panama. For this purpose, data were used, of agricultural gross domestic product at constant market prices of 2000 in dollars and consumption in tons of substances that deplete the ozone layer, these data were taken from the economic statistics of ECLAC.

The work uses a non-parametric programming methodology, based on the analysis of the data involved (Data Envelopment Analysis or DEA), which allows computing the Malmquist indices of productivity change. In this sense, the methodology used is similar to that used by Fare, Grosskopf, Norris and Zhang (1994), when analyzing various European economies, in our case Central American economies.

The results show that Costa Rica, Cuba, and Nicaragua are located in the Central American technological frontier, in the second period the rest of the countries present negative changes in productivity during the period studied, when analyzing the Central American economies, these results coincide with those found by Fare et al. (1994).

The rate between the exchange rate of GDPA and the rate of change in tons of ODS consumption is reflected in the Malmquist indices, in this sense the tons consumed for each unit of the rate of change in GDPA were reduced by 15.4% on average geometric, during the first period, while it grew 33.4% in the second period. The

Countries that stood out are Nicaragua in the first period and Costa Rica, Cuba, and Nicaragua in the second period. These results are close to those that would arise from applying the growth accounting methodology corresponding to the neoclassical theory as in Figure 2.

On the other hand, the technical efficiency at variable returns with ODS consumption guided by the Malmquist index reveals that the Central American countries were deficient at constant returns to scale, and only Nicaragua was efficient at constant and variable returns to scale. This is interpreted effective compliance with the agreements of the Montreal Protocol and the Vienna Convention, where the measures of the respective Ministries of the Environment have had a positive impact on the growth of GDPA, considering that one of the effects of the depletion of the layer of ozone is that the decrease in the yields of the productive subsystems (PNUMA 2005, Lopez et al. 2015, Marinero et al. 2015).

References

Argüelles, Vélez., Margarita., Benavides, González., Carmen (2006). Determinación del Impacto de la actividad económica regional sobre las emisiones de gases de efecto invernadero en Asturias. Universidad de Oviedo. Revista Asturiana de Economía- RAE No 36 2006.

Alam S., Morrison A. (2000): "Trade Reform Dynamics and Technical Efficiency: the Peruvian Experience", the World Bank Economic Review. Mayo 2000, Pag. # 309-330.

Afriat, S.N. (1972): Efficiency Estimation of Production Functions, International Economic Review, 13, 568-598.

Boles, J.N. (1966): Efficiency Squared – Efficiency Computation of Efficiency Indexes, Proceedings of the 39th Annual Meeting of the Western Farm Economic Association, pp 137-142.

Bjurek H., Hjalmarsson L (1995): "Productivity in Multiple Output Public Service: a Quadratic Frontier Function and Malmquist Index Approach". Journal of Public Economics. (56). 3. 447-60.

Brack, Ducan, 1996: International Trade and the Montreal Protocol. Royal Institute of International Affairs, 10 St James´s Square, London SW1Y 4 LE (Charity Registration No. 208 223) and Earthscan Publications Ltd, 120 Pentonville Road, London NI 9JN. ISBN 185383 345 2.

Banker, R.D., Charnes, A, and Cooper, W.W (1984): Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, 30, 1078-1092.

Coelli, T., J., 1996. A Guide to DEAP Versión 2.1: A Data Envelopment Analysis (Computer) Program. No 8/96 CEPA Working Papers Department of Econometrics; University of New England. Armidale, NSW 2351,. Australia. http://www.uneedu.ua/econetrics/cepawp.htm ISBN 1 86389 4969 ; ISSN 1327-435X. pp. 10- 46.

Caves D., Christensen L., Diewerte. (1982). "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity". Econometrica. Noviembre. 1393-414.

Charnes, A., W.W. Cooper, A. Y Lewin and L.M. Seiford (1995): Data Envelopment Anlysis: Theory, Methodology and Applications, Kluwer.

Debreu, G. (1951): The Coefficient of Resource Utilisation, Econometrica, 19, 273-292.

Dooslittle, Diane, M. 1989: Underestimating Ozone Depletion: The Meandering Road to the Montreal Protocolo and Beyond. 16 Ecology L.Q 407. Candidate for J.D 1989, School of Law (Boalt Hall), University of California at Berkeley; Certificat D'Etudes Politiques 1986.

Diario Oficial, 1995. Presidencia de la República El Salvador. Decreto Legislativo No 395 26 Noviembre (1992). Diario Oficial No 55 del Tomo No 326 del 20 de marzo de 1995. http://ns.marn.gob.sv/cd1/Legislacion/Reglamentos/sao.htm

Fare, R., S. Grosskopf, M. Norris and Z. Zhang (1994); Productivity Growth, Technical Progress, and Efficiency Changes in industrialized Countries, American Economic Review, 84, 66-83.

Fare, R., S. Grosskopf, and C.A.K. Lovell (1994): Production Frontiers, Cambridge University Press.

Fare, R., S. Grosskopf, and C.A.K. Lovell, 1978: Measuring the Technical Efficiency of Production. Journal of Economic Theory, 19, 150-162.

Fare R., Grosskopf S., Lindgren B., Roos P (1989): “Productivity Developments in Swedish”. Mimeo.

Farrel, G.D and C.A.K. Lovell (1957): The Measurement of Productive Efficiency, Journal of the Royal Statistical Society, A CXX, Part 3, 253-290.

Fulginitil., Perrin. (1997). “LDC Agriculture: nonparametric Malmquist Productivity Indexes”, Paper N° J-16527. Iowa State University.

González, C. A. Z. (2020). Crecimiento de la productividad total de los factores en la agricultura: análisis del índice de Malmquist de 14 países, 1979-2008. *REICE: Revista Electrónica de Investigación en Ciencias Económicas*, 8(16), 68-97.

González, C. A. Z. (2011). Technical efficiency of organic fertilizer in small farms of Nicaragua: 1998-2005. *African Journal of Business Management*, 5(3), 967-973.

Gonzalez, C. A. Z. (2011). Comparisons of LSMS-ISA data collection and dissemination efforts in Central America. *Journal of development and Agricultural Economics*, 3(8), 353-361.

Grosskopf, S. 1993. Efficiency and Productivity, in Fried, H.O., C.A.K Lovell and S.S. Schmidt (Eds), The Measurement of Productive Efficiency, Oxford University Press, New York, 160-194.

Hjalmarsson L., Veiderpassa A. (1992): “Productivity in Swedish Electricity Retail Distribution”. Scandinavian Journal of Economics. Supplement. (94). 193-205.

Koopmans, T.C. (1951): An Analysis of Production as an Efficient Combination of Activities, in T.C. Koopmans, Ed.,Activity Analysis of Production and Allocation, Cowles Commission for Research in Economics, Monograph No 13, Wiley, New York.

Leontief, W. (1936), Quantitative input-output relations in the economic systems of the United States, Review of Economics and Statistics, Vol 18, pp.105-125.

López-González, Á. S., Zúniga-González, C. A., López, M. R., Quirós-Madrigal, O. J., Colón-García, A. P., Navas-Calderón, J., ... & Rangel-Cura, R. A. (2015). Estado del arte de la medición de la productividad y la eficiencia técnica en América Latina: Caso Nicaragua. *Revista Iberoamericana de Bioeconomía y Cambio Climático* e-ISSN 2410-7980, 1(2), 76-100

Lovell, C.A.K (1993): Production Frontiers and Productive Efficiency, in Fried, H.O. , C.A.K Lovell and S.S Schmidt (Eds), The Measurement of Productive Efficiency, Oxford University Press, New York, 3-67.

Lanteri, N., Luis (2007): Productividad, desarrollo tecnológico y eficiencia. La Propuesta de los índices Malmquist.

Malmquist S. (1953): "Index Numbers and Indifference Surfaces". Trabajos de Estadística. (4). 209-42.

Miller, R.E. and P.D. Blair (1985) Input-Output Analysis: Foundations and Extensions. Pre ntice- Hall, Englewood Cliffs, New Jersey.

Montreal Protocol on Substances that Deplete the Ozone Layer, done Sept. 16, 1987, 26 I.L.M 1554 (ratified by the United States Mar. 14, 1988, entered into force Jan. I, 1898.

Marinero, A. E., Cañas, J. I. V., Catari, G., Martínez, L., Gómez, O. F. S., & González, C. A. Z. (2015). Análisis de la agenda pública y privada de la Bioeconomía en Centroamérica y el Caribe: Estudios de Caso de El Salvador, Honduras, Cuba y Nicaragua. Revista Iberoamericana de Bioeconomía y Cambio Climático, 1(1), 242-284.

Millennium Development Goals Indicators, The official United Nations site for MDG Indicators http://unstats.un.org/unsd/mdg/SeriesDetail.aspx?srid=753 Series Name: **Consumption of all Ozone-Depleting Substances in ODP metric tons** Goal: Goal 7. Ensure environmental sustainability Target: Target 7.A: Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources Indicator: Indicator 7.3 Consumption of ozone-depleting substances.

PNUMA: 2000. Programa de las Naciones Unidas para el Medio Ambiente. Progreso en el cumplimiento con el Protocolo de Montreal para la Protección de la Capa de Ozono en América Latina y el Caribe, al 31 de enero 2000.

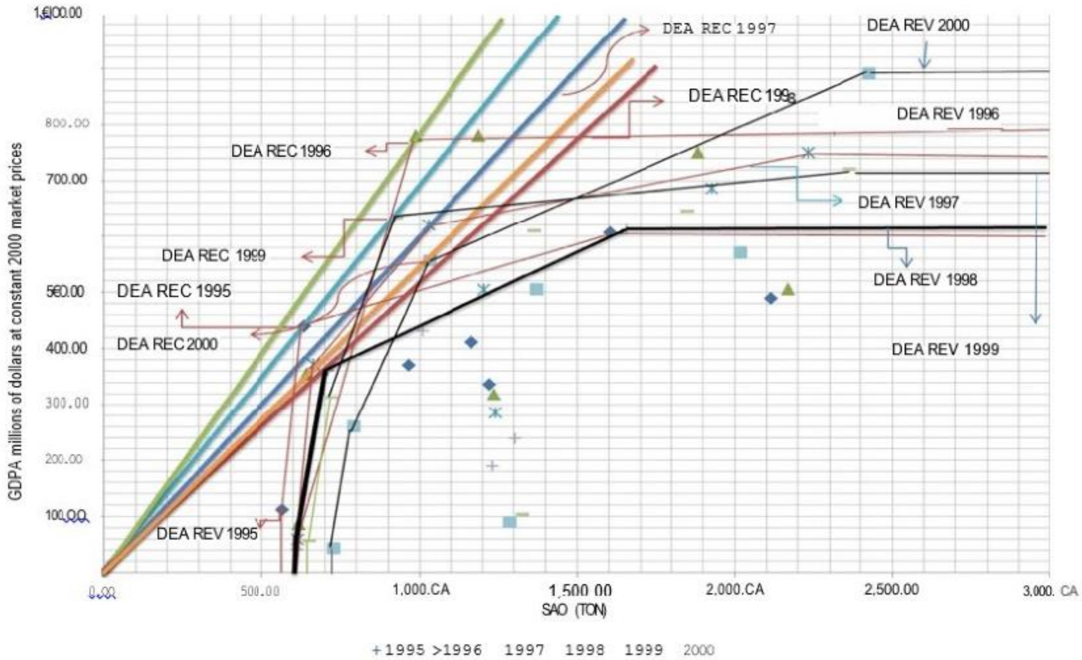
PNUMA/ORPALC: 2005. Manual de ciudadanía ambiental global. Capa de ozono. Proyecto de ciudadanía ambiental global. 2005. México D.F. www.pnuma.org http://www.pnuma.org/cidadania/index.php

Proops, J., Faber, M. and Wagenhals, G. (1993): Reducing CO2 Emissions: A Comparative Input-Output Study for Germany and the UK, Springer- Verlag, Heidelberg. http://unstats.un.org/unsd/mdg/SeriesDetail.aspx?srid=753

Piesse J., Thirtle C. (1997): "Sector-level Efficiency and Productivity in Hungarian Primary, Secondary and Tertiary Industries, 1985-1991". Eastern European Economics. (35). 5- 39.

SERNA, 1993: Secretaria de Recursos Naturales y Ambiente, 1993. Unidad Técnica de Ozono de Honduras. http://www.serna.gob.hn/comunidad/unidades/Documents/Logros%20UTOH%2008.pdf.

Anexes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GDPA millions of dollars at constant 2000 market prices
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