Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 14 Countries, 1979-2008

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Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

Abstract
In this paper I study levels and trends in agricultural output and productivity in 14 developing countries that account for a major portion of the Central American and Caribbean population and agricultural output. I make use of data of drawn from the Food and Agricultural Organization of the United Nations and my period study cover the period 1979-2008. The study uses data envelopment analysis (DEA) to derive Malmquist productivity indexes. The study examines trends in agricultural productivity over the period. Issues of catch-up and convergence, or in some cases possible divergence, in productivity in agriculture are examined within a global framework.

The results show an annual growth in TFP of 1.5 %, with efficiency change (or catch-up) contributing 0.1 % per year and technical change (or frontier shift) providing the other 1.4 %. In terms of individual country performance, the most spectacular performance is posted by Dominican Republic with an average annual growth of 3.9 % in TFP over the study period. Other countries with strong performance are, among other, Cuba, Barbados, Costa Rica, Panama and Guatemala have posted a TFP growth rate of only 2.9 every one.

JEL Classification: D: 24, O: 13, O: 47, P: 51, Q: 10.

Keyword: Total Factor Productivity Growth, Malmquist Index, Data Envelopment Analysis.

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1. Introduction

In the Central American and Caribbean countries the productivity growth in agriculture has been the subject matter for intense research over the last six decades. It has been including in the world study, where development economist and agricultural economist have examined the sources of productivity growth over time and of productivity differences among countries and regions over this period, where, Central American and Caribbean are included as individual countries. Productivity growth in the agricultural sector is considered essential if agricultural sector output is to grow at a sufficiently rapid rate to meet the demands for food and raw materials arising out of steady population growth. During the 1980s and 2010s a number of major analyses of cross-country differences in agricultural productivity were conducted (Coelli and Rao: 2003)[1].

The majority of these studies used cross-sectional data on approximately 40 countries to estimate a Coob-Douglas production technology using regression methods. The focus was generally on the estimation of the production elasticities and the investigation of the contributions of farm scale, education, and research in explaining cross-country labor productivity differentials[2].

In the past decade, the number of papers investigating cross-country differences in agricultural productivity levels and growth rates has expanded significantly. This is most likely driven by three factors. First, the availability of some news panel data sets, such as that produced by the Food and Agriculture Organization of the United Nation (FAO). Second, the development of new empirical techniques to analyze the type of data, such as the data envelopment analysis (DEA) and stochastic frontier analysis (SFA) techniques, described in Coelli et al. (1998). Third, a desire to assess the degree to which the Green Revolution, and other programs, have improved agricultural productivity in developing countries.

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[1] The authors include Hayami and Ruttan (1970, 1971), Kawagoe and Hayami (1983, 1985), Kawagoe et al., (1985), Capalbo and Antle (1988), and Lau and Yotopoulos (1989).

[2] Lau and Yotopolous (1980) also estiamted a translog functional form so as to illustrate the restrictions inherent in the Coob-Douglas production technology.

Table 1

Analyses of inter-country agricultural total factor productivity (TFP) growth, 1993-2011			
Authors	Method	Years	Countries
Fulginiti and Perrin (1993)	CD	1961-85	18 LDC
Bureau et al. (1995)	DEA & Fisher	1973-89	10 DC
Fulginiti and Perrin (1995)	DEA	1961-85	18 LDC
Craig et al(1997)	CD	1961-90	98
Lusigi and Thirtle (1997)	DEA	1961-91	47 Africa
Fulginiti and Perrin (1998)	CD (VC)	1961-85	18 LDC
Rao and Coelli (1998)	DEA	1961-95	97
Amade (1998)	DEA	1961-93	70
Fulginiti and Perrin (1999)	DEA & CD	1961-85	18 LDC
Martin and Mitra (1999)	Translog	1967-92	49
Wiebe et al. (2000)	CD	1961-97	110
Chavas (2001)	DEA	1960-95	12
Ball et al. (2001)	Fisher (EKS)	1973-93	10 DC
Suhariyanto et al. (2001)	DEA	1961-96	65 Asia/Africa
Suhariyanto and Thirtle (2001)	DEA	1961-96	65 Asia
Trueblood and Coggins (2003)	DEA	1961-91	115
Nin et al (2003)	DEA	1961-94	20 LDC
Rao and O´Donnell(2004)	DEA-SFA MF	1986-90	97
Coelli and Rao (2005)	DEA	1980-00	93
Coelli et al (2005)	DEA	1987-02	100 Belgium farms
Tong et al (2009)	DEA-SFA	1994-05	29 Chinise provinces
Hoang and Coelli (2009)	DEA	1990-03	28 OECD
Yeboah et al (2011)	DEA	1980-07	3 DC

In the table 1 I list 23 studies that have been conducted in the last Three decades.

The principal aim of this study is to provide up-to-date information on agricultural total factor productivity (TFP) growth over the past two decade (1994-2010) for 7 of agricultural producers in the Central America. It should be noted that the study by Wiebe et al. (2000) does analyze total factor productivity (TFP) growth for 110 nations over the 1961-1997 period; however, it does use the Cobb-Douglas production function, which introduces a number of restrictive assumptions, such as, constant production elasticities (and hence input shares) across all countries, Hicks-neutral technical change, plus the requirement that crop and livestock outputs be aggregated into a single output measure. The analysis in the present study uses the DEA technique to calculate the Malmquist TFP index numbers. This method does not make any of the above assumptions. However, it is susceptible to the effects of data noise, and can suffer from the problem of unusual¨ shadow prices, when degrees of freedom are limited.

Methodology

In this paper total factor productivity (TFP) is measured using the Malmquist index methods described in Färe et al. (1994 and Coelli et al. 1998, Chapter 10). This approach uses data envelopment analysis (DEA) methods to construct a piece-wise linear production frontier for each year in the sample. Hence, a brief description of DEA methods is provided prior to a description of the Malmquist TPF calculations.

1.1 Data envelopment analysis (DEA)

DEA is a linear programming methodology, which uses data on the input and output quantities of a group of countries to construct a piece-wise linear surface over the data points. This frontier surface is constructed by the solution of a sequence of linear programming problems-one for each country in the sample. The degree of technical inefficiency of each country (the distance between the observed data point and the frontier) is produced as by-product of the frontier construction method.

DEA can be either input-oriented or output-oriented. In the input-oriented case, the DEA method defines the frontier be seeking the maximum possible proportional reduction in input usage with output level held constant, for each country. While, in the output-oriented case, the DEA method seeks the maximum proportional increase in output production, with input levels, held fixed. The two measures provide the same technical efficiency scores, when a constant returns-to scale (CRS) technology applies, but are unequal when variable returns to scale (VRS) is assumed. In this paper a CRS technology is assumed (the reasons for this are outline in the Malmquist discussion below.) Hence the choice of orientation is not a big issue in this case. However, an output orientation has been selected because it would be fair to assume that, in agriculture, one usually attempts to maximize output from a given set of inputs, rather than the converse[3].

Given data for N countries in a particular time period, the linear programming (LP) problem that is solved for the ***i***th country in an output-oriented DEA model is as follows:

$$max_{\phi,\lambda}\phi,$$

$$st \quad -\phi y_i + Y\lambda \geq 0,$$

$$x_i - X\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (1)$$

Where

y_i is a M x 1 vector of output quantities for the *i*th country;

x_i is a K x 1 vector of input quantities for the *i*th country;

Y is a N x M matrix of output quantities for all N countries;

X is a N x K matrix of input quantities for all N countries;

λ is a N x 1 vector of weights; and

ϕ is a scalar.

[3] There are obvious exceptions to this. For example, where dairy farmers are required to fill a particular output quota, and attempt to do this with minimum inputs.

Observe that ϕ will be taking a value greater than or equal to 1, and that $\phi - 1$ is the proportional increase in outputs that could be achieved by the *i*th country, with input quantities held constant. Note also that $1/\phi$ defines a technical efficiency (TE) score that varies between 0 and 1 (and that this is the output-oriented TE score reported in my results).

The above LP is solve N times – once for each country in the sample. Each LP produce a ϕ and λ vector. The ϕ –parameter provides information on the technical efficiency score for the *i*th country. The peers of the *i*th country are those efficient countries that define the facet of the frontier against which the (inefficient) *i*th country is projected.

The DEA problem can be illustrated using a simple example. Consider the case where there are a group of five countries producing two outputs (e.g., wheat an beef). Assume for simplicity that each country has identical input vectors. These five countries are depicted in Figure 1. Countries A, B and C are efficient countries because they define the frontier. Countries D and E are inefficient countries. For country D the technical efficiency score is equal to

$$TE_D = \frac{0D}{0D'}, \tag{2}$$

And its peers are countries A and B. In the DEA output listing this country would have a technical efficiency score of approximately 70 & and would have nonzero λ-weights associated with countries. A and B. For country E the technical efficiency score is equal to

$$TE_E = \frac{0E}{0E'}, \tag{3}$$

And its peers are countries B and C. In the DEA output listing this country would have a technical efficiency

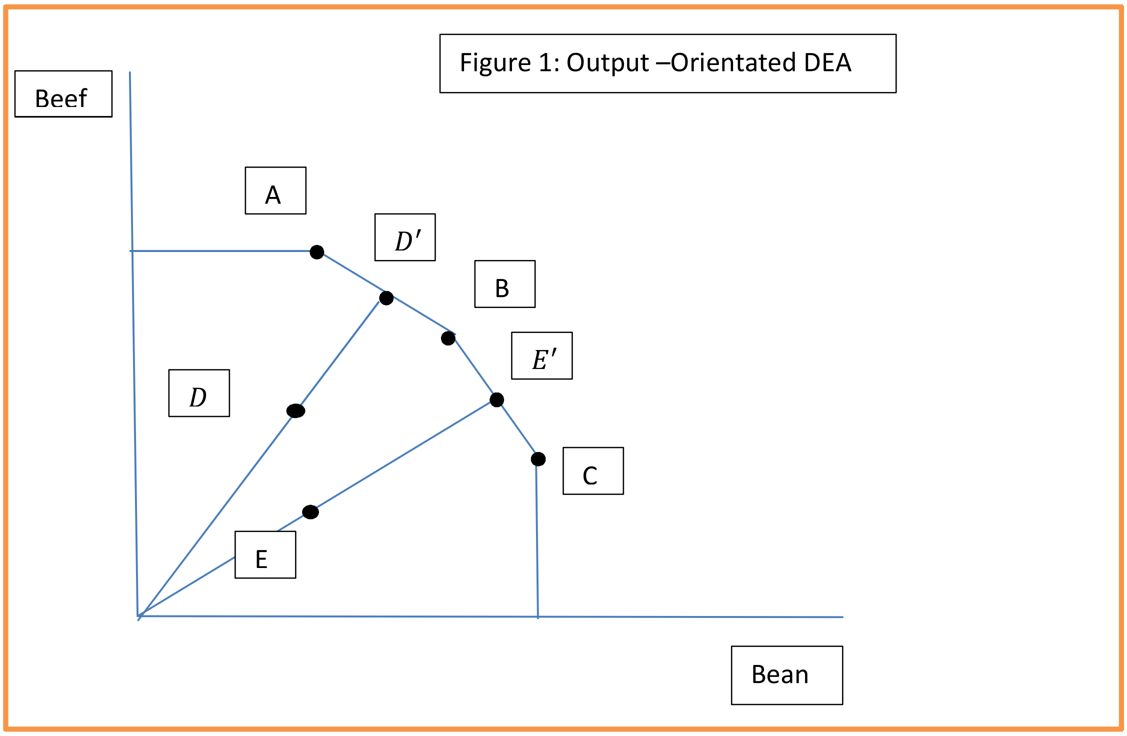

Figure 1: Output –Orientated DEA

Score of approximately 50 % and would have nonzero λ-weights associated with countries B and C. Note that the DEA output listing for countries A, B, and would provide technical efficiency scores equal to one and each countries would be its own peer. For further discussion of DEA methods see Coelli et al. (1998, Charter 6).

1.2 The Malmquist TFP index

The Malmquist index is defined using distance function. Distance functions describe a multi-input, multi-output production technology without the need to specify a behavioral objective (such as cost minimization or profit maximization). Both input distance functions and output distance functions may be defined. An input distance function characterizes the production technology by looking at a minimal proportional contraction for the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector. Only an output distance function is considered in detail in this paper. However, input distance functions can be defined and used in a similar manner. A production technology may be defined using the output set, $P(x)$, which represents the set of all output vectors, y, which can be produced using the input vector, x . That is,

$$P(x) = \{y\colon x\ puede\ producir\ y\} \qquad (4)$$

It is assumed that the technology satisfies the axioms listed in Coelli et al. (1998, Charter 3).

The output distance function is defined on the output set, $P(x)$, as:

$d_0(x, y) = \min\{\delta: (\frac{y}{\delta}) \epsilon\, P(x)\}$ (5)

The distance function, $d_0(x, y)$, will take a value that is less than or equal to 1 if the output vector, y , is an element of the feasible production set, $P(x)$. Furthermore, the distance function will take a value of unity if y is located on the outer boundary of the feasible production set, and will take a value greater than one if y is located outside the feasible production set. DEA-like methods are used to calculate the distance measure in this study. These are discussed shortly. The Malmquist TFP index measures the TFP change between two data points (e.g., those of a particular country in two adjacent time periods), by calculating the ratio of the distance of each data point relative to a common technology. Following Färe et al. (1994), the Malmquist (output-oriented) TFP change index between period s (the base period) and period t is given by

$m_0(y_s, x_s, y_t,) = [\frac{d_0^s(y_t,x_t)}{d_0^s(y_s,x_s)X}\, X \frac{d_0^t(y_t,x_t)}{d_0^t(y_s,x_s)}]^{1/2},$ (6)

Where the notation $d_0^s(y_t, x_t)$ represents the distance from the period t observation to the period s technology. A value of m_0 greater than 1 will indicate positive TFP growth from period s to period t while a value less than one indicates a TFP decline. Note that equation (6) is, in fact, the geometric mean of two TFP indices. The first is evaluated with respect to period s technology and the second with respect to period t technology.

An equivalent way of writing this productivity index is

$$m_0(y_s, x_s, y_t, y_t\,) = [\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)X}\, X \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)}]^{1/2}, \quad (7)$$

Where the ratio outside the square brackets measures the change in the output-oriented measure of Farrel technical efficiency between periods s and t. That is, the efficiency change is equivalent to the ratio of the technical efficiency in period t to the technical efficiency in period s. The remaining part of the index in equation (2) is a measure of technical change. It is the geometric mean of the shift in technology between the two periods, evaluated at x_t and also at x_s.

Following Färe et al. (1994), and given that suitable panel data are available, the required distance measures for the Malmquist TFP index are calculated using DEA-like linear programs. For the *i*th country, four distance functions are calculated in order to measure the TFP change between two periods, s and t. This requires the solving of four linear programming (LP) problems. Färe et al. (1994) assume a constant returns-to-scale (CRS) technology in their analysis. The required LPs are:

$[d_0^t(y_t, x_t)^{-1} = max_\phi, \lambda, \phi,$

$st \quad -\phi y_{it} + Y_t\lambda \geq 0,$

$x_{it} - X_t\lambda \geq 0,$

$\lambda \geq 0,$ (8)

$$[d_0^t(y_s, x_s)^{-1} = max_{\phi}, \lambda, \phi,$$

$$st \quad -\phi y_{is} + Y_t\lambda \geq 0,$$

$$x_{is} - X_t\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (10)$$

$$[d_0^s(y_t, x_t)^{-1} = max_{\phi}, \lambda, \phi,$$

$$st \quad -\phi y_{it} + Y_s\lambda \geq 0,$$

$$x_{it} - X_s\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (11)$$

Note that in LPs (10) and (11), where production points are compared to technologies from different time periods to 1, as it must be when calculating standard output-oriented technical efficiencies. The data point could lie above the production frontier. This will most likely occur in LP (11) where a production point from period t is compared to technology in an earlier period, s. If technical progress has occurred, then a value of $\phi < 1$ is possible. Note that it could also possibly occur in LP (10) if technical regress has occurred, but this is less likely.

One issue that must be stressed is that the returns-to-scale properties of the technology are very important in TFP measurement. A CRS technology is used in this study for two reasons. First, given that the analysis involves the use of aggregate country-level data, it does not appear to be sensible to consider a VRS technology. That is, how is it possible for a sector to achieve scale economies? For example, the index of crop output for Nicaragua is similar, but their average farm sizes are quite different. Hence, what can be sensibly concluded if a VRS technology is estimated and it is reported that these countries face decreasing returns to scale? The use of a VRS technology when the summary data are expressed on an ¨average per farm¨ could be discussed, but when dealing with aggregate data (as is the case in this study) the use of a CRS technology is the only sensible option.

In addition to the above comment regarding the use of aggregate data, a second argument for the use of a CRS technology is applicable to both firm level and aggregate data. Grifell-Tatjé and Lovell (1995) use a simple one-input, one –output example to illustrate that a Malmquist TFP indez may not correctly measure TFP changes when VRS is assumed for the technology. Hence, it is important that a CRS technology be used in calculating Malmquist TFP indices using DEA. Otherwise, the resulting measures may not properly reflect the TFP gains or losses resulting from scale effects.

2. Data

The present study is based on data drawn from the FAOSTAT system of the FAO Statistic Division of the FAOSTAT Agriculture. It is possible to access and download all the necessary data from the Web site of the FAO[4]. The following are of the features of the data series used.

2.1 Country coverage

The study includes 14 countries. These are Central American and Caribbean countries, account for roughly 7 %[5] of the Latin America´s agricultural output as well as 32 % of Latin America´s agricultural population. The countries included in the study are:

1	Bahamas
2	Barbados
3	Belize
4	Costa Rica
5	Cuba
6	Dominican Republic
7	El Salvador
8	Guatemala
9	Honduras
10	Jamaica
11	Nicaragua
12	Panamá
13	Saint Lucia
14	Saint Vicent and the Grenadines

2.2 Time period

Results are presented for the period 1979 to 2008. The initial intention was to study the 1969-2010 period; however, the analysis has been restricted to this shorter period since labor force data were not readily available for the years 1979-2008 from the FAO or ILO sources. These years will be included in the subsequent stages of the project when appropriate labor data are obtained.

2.3 Output series

Due to the problems of degrees freedom associated with the application of DEA methods, the presents study uses two output variables, viz., crops and livestock output variables. The output

[4] http://www.fao.org/corp/statistics/es/

[5] Data was estimated with database of CEPAL: Latin America Economic Commission. The ratio for agricultural production was estimated with data 2010, using Central America agricultural production and total agricultural production in Latin America. The ratio for agricultural population was estimated for 2011 using ECLAC-CAPALSTAT Social Indicators and statistics population, total population; it is given in thousands of persons projected to 2011.

series for these two variables are derived by aggregating detailed output quantity data on 160 agricultural commodities. The following steps are used in the construction of data.

For the year 1999-2001, output aggregates are drawn from Table 5.4 in Rao (1993). These aggregates are constructed using international average prices (expressed in U.S dollars) derived using the Geart-khamis method (See Rao, 1993, Chapter 4 for details) for the benchmark year 1990. Thus the output series for 1999-2001 are at constant prices, expressed in a single currency unit.

The 1999-2001 output series are then extended to cover the study period 1979-2009 using the FAO production index number series for crops and livestock separately. The series that are derived using this approach are essentially equivalent to the series constructed using international average prices and the actual quantities produced in different countries in various years.

Tables of the output aggregates for the 7 countries for years 1979 and 2009 are available from the authors on request. These tables demonstrate the differences in output mix across different countries. There are many countries that are mainly producers, while the remaining countries have a fair balance between crops and livestock. A point to note here is the definition of the FAO production index, the output concept used here is the output from the agriculture sector, net of quantities of various commodities used as feed and seed. This is the reason for not including feed and seed in the input series.

Another point regarding the output series that is important to remember is the fact the output series are based on 1999-2001 international average prices. So the output series would change when the base is shifted from 1999-2001 to another period, thus potentially influencing the final results. In this study it was decided that it is more appropriate to use 1999-2001 prices as the basis for the study spanning 1979 to 2009 rather than using 1979 or 2009 international average prices.

The FAO indices of agricultural production show the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 1999-2001. They are based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. The resulting aggregate represents, therefore, disposable production for any use except as seed and feed.

All the indices at the country levels are calculated by the Laspeyers formula. Production quantities of each commodity are weighted by 1999-2001 average international commodity prices and summed for each year. To obtain the index, the aggregate for a given year is divided by the average aggregate for the base period 1999-2001.

Since the FAO indices are based on the concept of agriculture as a single enterprise, amounts of seed and feed are subtracted from the production data to avoid double counting them, once in the production data and once with the crops or livestock produced from them. Deductions for seed (in the case of eggs, for hatching) and for livestock and poultry feed apply to both domestically produced and imported commodities. They cover only primary agricultural products destined to animal feed (e.g. maize, potatoes, milk, etc.). Processed and semi-processed feed items such as bran, oilcakes, meals and molasses have been completely excluded from the calculations at all stages.

It should be noted that when calculating indices of agricultural, food and nonfood production, all intermediate primary inputs of agricultural origin are deducted. However, for indices of any other commodity group, only inputs originating from within the same group are deducted; thus, only seed is removed from the group “crops” and from all crop subgroups, such as cereals, oil crops, etc.; and both feed and seed originating from within the livestock sector (e.g. milk feed, hatching eggs) are removed from the group “livestock products”. For the main two livestock subgroups, namely, meat and milk, only feed originating from the respective subgroup is removed.

The “international commodity prices” are used in order to avoid the use of exchange rates for obtaining continental and world aggregates, and also to improve and facilitate international comparative analysis of productivity at the national level. These” international prices”, expressed in so-called” international dollars”, are derived using a Geary-Khamis formula for the agricultural sector. This method assigns a single “price” to each commodity. For example, one metric ton of wheat has the same price regardless of the country where it was produced. The currency unit in which the prices are expressed has no influence on the indices published.

The commodities covered in the computation of indices of agricultural production are all crops and livestock products originating in each country. Practically all products are covered, with the main exception of fodder crops. The category of food production includes commodities that are considered edible and that contain nutrients. Accordingly, coffee and tea are excluded along with inedible commodities because, although edible, they have practically no nutritive value.

Indices for meat production are computed based on data for production from indigenous animals, which takes account of the meat equivalent of exported live animals but excludes the meat equivalent of imported live animals. For index purposes, annual changes in livestock and poultry numbers or in their average live weight are not taken into account.

The indices are calculated from production data presented on a calendar year basis.

The FAO indices may differ from those produced by the countries themselves because of differences in concepts of production, coverage, weights, time reference of data and methods of calculation.

2.4 Input series

Given the constraints on the number of input variables that can be used in a DEA analysis, this analysis consider only six input variable. Details of these variables are given below.

Land: This variable covers arable land, land under permanent crops as well as the area under permanent meadows and pastures. The area is given in 1000 Ha by country.

Tractors: This variable covers the total number imported quantity of agricultural tract, but excludes garden tractors, used in agriculture. It is important to note that only the number of tractors is used as the input variable with no allowance made to the horsepower of the tractors.

Labor: This variable refers to the economically active population in agriculture. This population is defined as all persons engaged or seeking employment in an economic activity, whether as employers, own-account workers, salaried employees, or unpaid workers, assisting in the operation of a family farm or business. The economically active population in agriculture includes all economically active population in agriculture engaged in agriculture, forestry, hunting, or fishing. This variable obviously overstates the labor input used in agricultural production, where the extent of overstatement depends upon the level of development of the country.

Livestock: The livestock input variable used in the study is the sheep equivalent of seven categories of animals used in constructing this variable. The categories considered are: asses, cattle, goats, horses, mules, pig and sheep. Numbers of these animals are converted into sheep equivalents using conversion factors: 8.0 for cattle; 1.00 for sheep, goat, and pig[6].

Fertilizer: This variable is measured as the sum of Ammonia, Ammonium Nitrate, Ammonium Phosphat (P2o5), Ammonium Phosphate (N), Ammonium Sulphate, Ammonium SulphateNitrate, Basic Slag, Calcium Ammonium Nitrate, Calcium Cyanamide, Calcium Nitrate, Complex Fertilizer (K2o), Concent Superphosphate, Crude Salts To 20 % K2o, Ground Rock Phosphate, Muriate 20-45 % K2o, Muriate Over 45 % K2o, Nitrogenous fertilizers, Oth Complex Fert (P2o5), Other Nitrogenous Fert, Other Phosphate Fertil, Other Potash Fertilizers, Potassium Sulphate, Single Superphosphate, Sodium Nitrate, and Urea contained in the commercial fertilizers consumed. This variable is expressed in tonnes (metric tonnes).

Irrigation: In this study, the area equipped for irrigation is used as a proxy for the capital infrastructure associated with irrigation of farmlands[7].

Results

The results of the DEA and TFP calculations are summarized in this section. Given that there are 30 annual observations on 14 Central American and Caribbean countries, there is a lot of

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[6] The conversion figures used in this study correspond very closely with those used in the 1870 study of Hayami and Ruttan and Coelli and Rao. In this calculation buffalo is don´t included because in Central America area they don´t exist. Chicken numbers are not included in the livestock figures.

[7] This irrigation variable includes the total area equipped for irrigation. Due to the use of different data source and overlaps in definitions and classifications, the sum of individual land use category data may exceed ¨total land area¨ it is given by (1000 Ha). Examples of such instances include forest and agriculture land with tree cover- such as rubber plantations, permanent tree crops, range land and agro-forestry and shifting cultivation areas.

computer output to describe. The calculations involved the solving of 14 x (30 X 3 - 2) = 1,232 LP problems.

Table 2

Means of technical efficiency for the central american and caribean countries, 1979-2008

Country	1980	1990	2000	2008
Bahamas	0.94	1	1	1
Barbados	1	1	1	1
Belize	1	1	1	1
Costa Rica	1	1	1	1
Cuba	0.85	0.96	1	1
Dominican Republic	1	1	1	1
El Salvador	1	1	1	1
Guatemala	1	1	1	1
Honduras	1.08	1	0.99	1
Jamaica	1	1	1	1
Nicaragua	0.93	0.76	1	1
Panama	1.12	1	1	1
Saint Lucia	1	1	0.86	1
Saint Vicent and the Grenadines	0.96	1	1	1
Mean	**0.99**	**0.98**	**1.0**	**1.0**

There are thousands of pieces of information on the efficiency scores and peers of each country in each year. Furthermore, measures of technical efficiency change, technical change, and TFP change for each country in each pair of adjacent years have been calculated.

Hence, by necessity only selections of the results are presented in this paper. Information on the means of measures of technical efficiency change, technical change, and TFP change for each country (over the 30 – year sample period) and the mean changes between each pair of adjacent year (over the 14 central American and Caribbean countries) are provided. Furthermore, means for certain groups of countries and plots of the TFP trends of some selected countries are presented. In addition of this, a table of peers for all countries in the first year (1979), the first and in the final year (2008) is provided[8]. Each of these sets of results is now discussed in turn.

Average technical efficiency scores in 1980, 1989, 2000 and 2008 are reported in table 2 for the countries and the full sample. Note that the average technical efficiency score of 0.98 in 1979 implies that these countries are, on average, producing 98 % of the output that could be potentially produced using the observed input quantities[9]. It is interesting to note those countries with the lowest mean technical efficiency scores in 1979 (Bahamas, Cuba, Honduras and Panama) also achieved the largest increase in mean technical efficiency over the sample period. This provides evidence of catch-up in these countries, which was not found in many of the studies

[8] As refer the theory these can obviously change from year to year, but it is not feasible to present this information for every year (Coelli and Roa: 2003).

[9] This figure should be interpreted with care. No attempt has been made to adjust the data for difference in climate, soil quality, labor quality, etc.

listed in table 1.   This is most likely due to the fact that the data in this study span the past three decades, while the majority of these other studies consider the 1960-2003.

Table 3

Peers from DEA, 1979 and 2008

		Peer					
	Country	**1979**			**2008**	**Count***	
1	Bahamas	1			1	0	0
2	Barbados	2			2	0	0
3	Belize	3			3	1	0
4	Costa Rica	4			4	0	0
5	Cuba	5			5	0	0
6	Dominican Republic	6			6	0	0
7	El Salvador	7			7	0	0
8	Guatemala	8			8	0	0
9	Honduras	10	11	3	9	0	0
10	Jamaica	10			10	1	0
11	Nicaragua	11			11	1	0
12	Panama	12			12	0	0
13	Saint Lucia	13			13	0	0
14	Saint Vicent and the Grenadines	14			14	0	0

*The count is the peer count. That is, the number of time that country acts as a peer of another country.

This information on changes in average technical efficiency only tells the ¨catch-up¨ part of the productivity story. TFP change can also appear in the form of technical change (or frontier shift). The means of the measures of technical efficiency change, technical change and TFP change for each country (over the 30-year sample period) are presented in the table 4. Table 5 and 6, respectively, show the unweighted and weighted annual averages (averaged over the 14 countries) of efficiency change, technical change, and TFP change.

Table 4

Mean technical efficiency change, technology change, and TFP change, 1979-2008

	Country	**Efficiency Change**	**Technical Change**	**TFP Change**
6	Dominican Republic	1.000	1.039	1.039
5	Cuba	0.996	1.035	1.031
2	Barbados	1.000	1.029	1.029
4	Costa Rica	1.000	1.029	1.029
12	Panama	1.004	1.025	1.029
8	Guatemala	1.000	1.025	1.025
7	El Salvador	1.000	1.021	1.021
10	Jamaica	1.000	1.019	1.019
1	Bahamas	1.002	1.009	1.011
11	Nicaragua	1.000	1.001	1.001
13	Saint Lucia	1.000	0.999	0.999
9	Honduras	1.003	0.99	0.993
14	Saint Vicent and the Grenadines	1.000	0.991	0.991
3	Belize	1.000	0.989	0.989
Mean		1.01	1.014	1.015

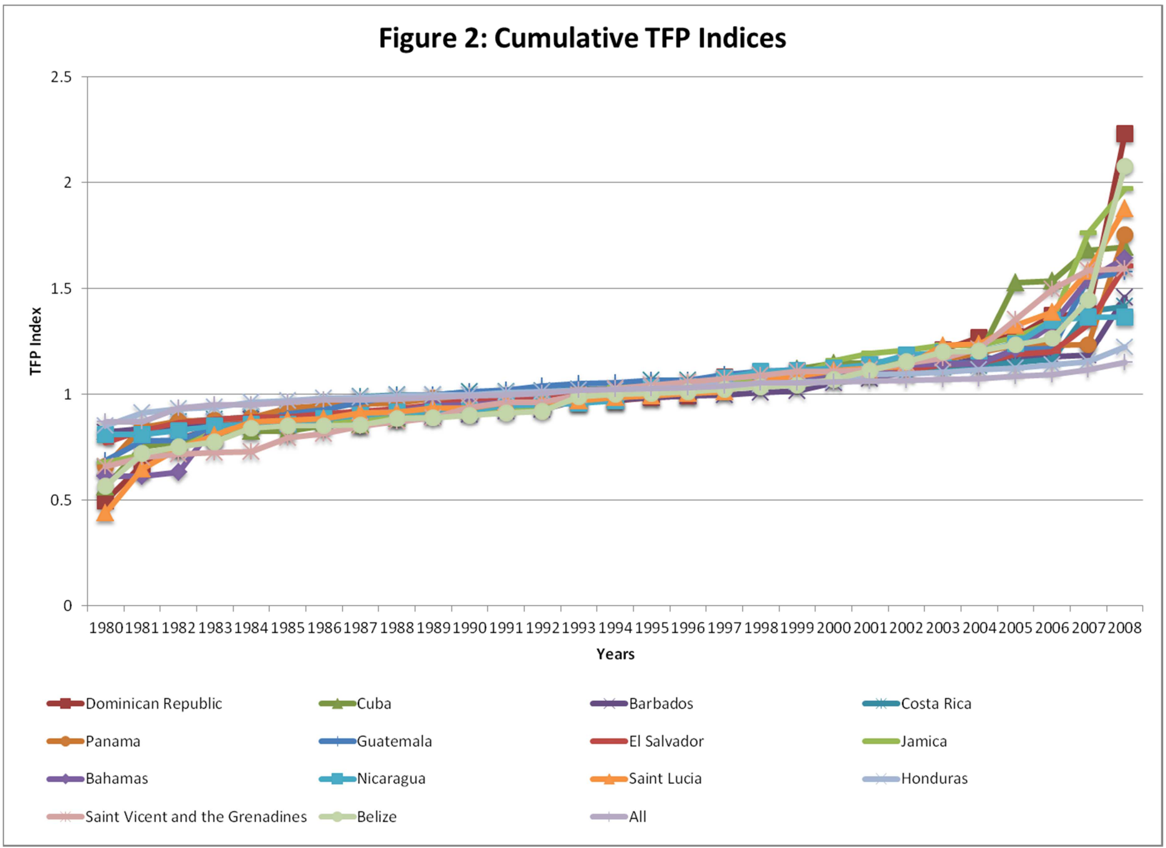
Table 5

Annual mean tecnical efficiency, technology change, and TFP change, 1979-2008

Year*	Efficiency Change	Technical Change	TFP Change
1980	0.989	0.946	0.935
1981	0.998	1.056	1.055
1982	1.015	1.136	1.153
1983	0.989	1.01	0.999
1984	1.008	0.954	0.962
1985	0.992	1.084	1.075
1986	0.994	0.877	0.872
1987	1	0.985	0.985
1988	0.988	1.076	1.062
1989	1.042	0.935	0.975
1990	0.977	1.142	1.116
1991	1.013	0.861	0.872
1992	1.01	1.059	1.07
1993	0.998	1.06	1.058
1994	1.01	1.021	1.031
1995	0.975	1.003	0.977
1996	1.012	1.082	1.095
1997	0.985	0.967	0.953
1998	0.997	1.042	1.038
1999	1.01	1.016	1.026
2000	0.989	1.099	1.086
2001	1.011	1.053	1.065
2002	1.008	0.996	1.005
2003	1.009	1.017	1.027
2004	1	0.995	0.995
2005	1.003	0.971	0.974
2006	0.988	0.962	0.95
2007	1.004	1.018	1.022
2008	0.999	1.057	1.055
Mean	**1.01**	**1.014**	**1.015**

*Note that 1981 referes to the change betew een 1980 and 1981, etc.

In table 3 we can identify all those countries that define the frontier technology for the years 1979 and 2008 (in the vicinity of their observed output and input mixes). The table shows that there are 13 and 14 countries that are on the frontier in 1979 and 2008, respectively. All the countries, which were on the frontier in 1979, (except Honduras), were longer in the frontier in 2008. Table 3 also provides a list of countries that define the best practice (peer) for each of the countries that are not on the frontier. It is interesting to observe the changes in the sets of peer countries over the three periods. For example, in 1979 only Honduras had the Jamaica, Nicaragua and Belize as its peers. However, in 2008 all countries remained in the peer country set, the other country in the new set being Honduras. Sets of peer countries defining best practice for countries in Cuba seem to be relatively stable over the study period.



The last two columns of Table 3 show the number of times each of the efficient countries on the frontier appears as a peer for the technically inefficient countries. Countries that do not appear as a peer for any other country may be considered to be on the frontier due to the unique nature of their input mixes. For example, Bahamas, Barbados, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Panama, Saint Lucia, Saint Vicent and the Grenadines does not appear as a peer for any country in 1979. In contrast, all countries appear as a peer for 14 countries in 2008.

Table 4 shows the mean technical efficiency change, technical change, and TFP change for the 14 countries over the period 1980 to 2008. Countries in the table are presented in descending order of the magnitude of the TFP changes. The table shows Dominican Republic and Cuba as the two countries with maximum TFP growth. Dominican Republic 4.0 % average growth in TFP, which is due to 4 % growth in technical change. . Barbados, Costa Rica, Panama and Guatemala respectively, exhibit TFP growth rate of 2.9, 2.9, 2.5 and 2.5 %. The unweighted average (across all countries) growth in TFP is 1.5 %.

Table 5 and 6 show the annual average technical efficiency change, technical change, and TFP change using, respectively, unweighted (where each country change is weighted by the country´s share in total agricultural output). These tables show the effect of using weights on the annual averages derived. Unweighted average show only 1.5 % growths in TFP whereas the weighted TFP growth over the period is 3.0 %. The results show that the use of unweighted averages understates the changes in TFP and in its components. Another implication of this difference is that TFP growth has been higher in countries with a higher share of global agricultural output. It seems reasonable to argue that for purpose of assessing countries and global performance a weighted average (across countries) of annual growth rates is more appropriated.

Tables 5 and 6 show that over the whole period there has been no technological regression though for some individual years there has been son evidence of technological regression. The extent of technological regression seems to be less serious when weighted average changes are considered.

Figure 2 shows cumulative TFP indices from 1979 to 2008 for different countries. From the figure it is evident that Dominican Republic has the highest cumulative growth by 2008, followed by Cuba.

Figure 3 summarizes our estimated shadow shares obtained from DEA frontiers used in computing the Malmquist TFP indices. Summary information on these shares is also given in Table 9 and 10. The top two series in Figure 3 represent the value shares for crops and livestock (both sum to unity) over the study period. These shares appear to be fairly steady over the period, with crops accounting for more than 50 % of the total output in most years.

The six series graphed at the bottom of Figure 3 represent the shadow input shares resulting from the application of the DEA methodology. The figure serves to demonstrate the plausibility of the input shares derived here. The average labor share shows a steady decline from 28,5 % in 1979 to 24,2 % in 2008. The share of land, aggregated over all the countries, seems to be quite stable at around 11 %. While the share of tractors remained essentially the same, the share of tractors remained essentially the same, the shares of fertilizer and livestock have shown small increase.

Table 10 shows the country-specific output and input shares underlying the TFP indices reported here. These shares are averaged over the study period 1997 to 2008. These shadow shares seem to be quite meaningful. For example, India shows 71 % share for crops and 29 % for livestock confirming the importance of crops in India. Similarly, in the Netherlands the share of livestock is shown to be 97,1 %. Similar livestock shares are shown for Norway (99.4%), Switzerland (95.1%), and Finland (96.6 %).

The last six columns of Table 10 show the shares of the six inputs. These shares also appear to be meaningful and consistent with the general factor endowments enjoyed by these countries. For example, the shadows shares of labor are quite high in countries like the United States (64.1 %), Canada (53.9%), and Australia (58.6 %). Labor share is abundant and agriculture is very labor intensive. India and Indonesia, respectively, have shadow labor shares of 44.5 and 42.2 %, respectively. In countries where land is a limiting factor its shadow share is quite high. For example, in the Netherlands the share is 27.7 %. In Japan and Israel the land shares are, respectively, 56.4 % and 47.2 %. These large shares for land also reflect the scarcity of land result in from increasing urbanization of agricultural land.

3. Conclusions

This paper presents some important findings on levels and trends in Central American and Caribbean productivity over the past three decades. The results presented here examine the growth in agricultural productivity in 14 countries over the period 1979 to 2008. The results show an annual growth in TFP of 1.5 %, with efficiency change (or catch-up) contributing 0.1 % per year and technical change (or frontier shift) providing the other 1.4 %. There is little evidence of the technological regression discussed in a number of the paper listed in Table 1. This is most likely a consequence of the use of a different sample period and an expanded group of countries. In terms of individual country performance, the most spectacular performance is posted by Dominican Republic with an average annual growth of 3.9 % in TFP over the study period. Other countries with strong performance are, among others, Cuba, Barbados, Costa Rica, Panama and Guatemala. Cuba has a TFP growth rate of 3.1 whereas Barbados, Costa Rica and Panama have posted a TFP growth rate of only 2.9 % every one.

Examining the questions of catch-up and convergence, I find that those countries that were well below the frontier in 1979. These results indicate a degree of catch-up in productivity levels between high-performance and low performance countries. These results are of interest since they indicate an encouraging reversal (during 1979-2008) in the phenomenon of negative productivity trend and technological regression reported in some of the earlier studies for the period 1961-1985.

Though the results are quite plausible and meaningful, the author is quite conscious of the data limitations and the need for further work in this area. Future work could include: a) an examination of the robustness of the results to shifts in the base period for the computation of output aggregates; b) the inclusion of pesticides, herbicides, and purchased feed and seed in the input set; c) an investigation of the effects of land quality, irrigation, and rainfall; and d) utilization of parametric distance functions to study the robustness of the findings to the choice of methodology.

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