Comparison of coffee production in Mexico against the 30 best producing countries

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***Abstract* - Coffee is considered as a global exporting and importing goods. In total, there are approximately 80 countries producing coffee, where Brazil, as the biggest coffee producer, produces around 6,000 million pounds of coffee every year. In this article, we analyze productivity of the 30 biggest coffee producers based on Data Envelopment Analysis. The results show that Brazil, Vietnam and Colombia are the only 100% efficient countries. The average efficiency of all countries is 22.631% with SD 30.115%. Mexico belongs among the inefficient countries, as its efficiency is 14.907%. With a post-projection analysis, Mexico should increase its production (measured by pounds per year) by 6.69 times or increase the production potential from each hectare.**

I. INTRODUCTION

Coffee is one of the main generic products that are sailed in the world market. The coffee production is carried out in tropical zones and currently 80 countries cultivate coffee in its different types [1]. The top ten producing countries are Brazil, Vietnam, Colombia, Indonesia, Ethiopia, Honduras, India, Uganda, Mexico and Guatemala. [2] The main producer, regarding the absolute production, is Brazil with 3,308 thousand of tons produced in 2012, which is approximately 2.35 times more than the second biggest producer Vietnam. Mexico is placed as the 6th biggest coffee producer with 246 thousand tons in 2012. Table I summarizes the coffee production of the main global producers between 2006 and 2012. [1]

TABLE I
PRINCIPAL PRODUCERS OF GREEN COFFEE, 2006-2012, THOUSANDS OF TONS [1]

Country	2006	2007	2008	2009	2010	2011	2012
Brazil	2,573	2,249	2,797	2,440	2,907	2,700	3,038
Vietnam	985	1,251	1,056	1,058	1,106	1,277	1,292
Indonesia	682	676	698	683	684	639	657
Colombia	725	757	689	469	535	469	465
India	274	288	262	262	290	302	314
Mexico	280	269	260	264	245	237	246
Guatemala	235	244	248	249	248	243	248
Perú	273	226	274	243	265	332	303
Ethiopia	241	273	260	265	371	377	276
Honduras	214	236	241	231	229	282	300

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Brazil as the top coffee producing country has share of 40% of the global coffee supply, whereas Vietnam as the second largest coffee producer has a share of approximately 20%. The coffee trade is one of Brazil's most important industries. In 2014, about two million hectares of agricultural land was allotted for harvesting green coffee. [3] What is more, regarding the data from 2016, Brazil was also the biggest coffee consumer in the South American and second biggest consumer in the world with 5.9 kilograms per capita per year. Globally, the biggest coffee consumer is Germany with 6.5 kilograms of coffee per capita in 2016, followed by Brazil, Italy (5.6 kg), France (5.1 kg), Japan (3.5 kg) and Ethiopia (2.3 kg). The European Union as unit consumes in average 4.5 kilograms of coffee per capita per year. [4]

The coffee sector in Mexico has been an important part of its history, as well as a part of economic, political, social and cultural development of the country. Most of the production is generated by small peasants and indigenous people, connected to the international market through regional hoarders and brokers and transnational companies. The Mexican coffee production is mainly concentrated on the South of the country. [5] The biggest coffee producing state is Chiapas (532,582.79 tons), followed by Veracruz (369,455.21) and Puebla (202,947.48). The total production reached 1,336,882.11 tons in 2012. Table II summarizes the coffee production of the top 12 Mexican states.

TABLE II
PRODUCTION INDICATORS OF CHERRY COFFEE IN MEXICAN STATES, 2012 [1]

State	Production (tons)	Production value (thousands of pesos)
Chiapas	532,582.79	3,481,899,684.22
Veracruz	369,455.21	2,584,749,838.42
Puebla	202,947.48	1,564,469,924.11
Oaxaca	117,439.81	440,579,491.44
Guerrero	48,447.37	186,851,849.40
Hidalgo	32,880.30	212,070,140.00
San Luis Potosí	11,829.87	18,784,136.00
Nayarit	10,785.20	90,265,603.75
Jalisco	5,311.38	16,366,251.20
Colima	2,043.58	16,366,251.20
Tabasco	953.68	7,131,360.75
Querétaro	108.00	972,000.00
Total in Mexico	1,336,882.11	8,647,580,349.05

World coffee consumption has undergone significant changes in the world's major import and export centers. These changes have been linked to changes in the way of life of industrialized societies, causing a decline in the average levels of coffee consumption per inhabitant in some areas and in others had such success within the market that was becoming

its main activity. [6] These changes for the producers have been an opportunity to the growth of the consumption of coffee world. This has an important weight in the world trade reaching to generate annual income more than the 15,000 dollars for the exporting countries and giving an occupation to more than 20 million people. [7]

Currently, Mexico produces excellent amounts of coffee since its typography, soils and climates allow Mexico to cultivate and produce different variations of coffee. One of the main producing states in Mexico is Chiapas. Chiapas has the necessary conditions to confronting and competing in an international market. [4] However, the absence of economic policy tools that integrate risk and uncertainty will not allow in the short-term to increase the income of small producers. "This occurs on a surface of 761 000 hectares in twelve states of the republic and production involves more than 282,000 producers among which are found in a majority of indigenous." [5]

In the year 2016, Mexico was immersed in the worst crisis of the coffee production history, generating the conditions that relocate it in the competition of market of coffee production went through a dynamism in that market. However, the production was observed downwards by the lack of a technology choice in the field to combat pests. This plague is known as the disease of the rust that is a fungus, which weakens the plants and causes the fruit of the coffee to fall before its maturation. [1] This plague has spread around the world and has caused casualties in the production of coffee and exorbitant losses.

The main problems of coffee production have been documented by [8] and [9]. These authors state that the most important problems are the low technological level of the producer, that the varieties of coffee cultivated are not the most appropriate, the deficient management of the agricultural practices and the training in the technical and commercial planes. Although the coffee production has a high economic and social value, it also plays an important and essential activity in any part of the world. Coffee production is given under rigorous systems that not only benefit the people, but the area where "Sowing creating future benefits for a major harvest and production thus reducing erosion problems thus promoting unique and essential incentives to support the growth and competitiveness of individual economic growth." [5]

Based on this information and the mishaps that have been over these 2 years, the production of coffee in Mexico has been able to succeed thanks to the implementation of new control programs. The programs include the renovation of coffee plantations in the entity, so that soon its benefits can be extended to about 250,000 hectares producing arabica beans in Chiapas and coffee robusta in Oaxaca. [10] These are biotechnology products that, by stopping the rust fungus, lead to higher crop productivity, which will allow Mexico to remain within the first places in the production of certified organic coffee.

The main objective of this article is to analyze the coffee production in Mexico among the 30 best coffee producing countries around the world. For this reason, we use a benchmarking analysis base on multi-criteria decision analysis (MCDA).

II. MATERIALS AND METHODS

Data Envelopment Analysis

The Data envelopment analysis (DEA) enables to assess various Decision-Making Units (DMUs) with regard to their abilities to cover multiple inputs into multiple outputs. Each DMU can have various amounts of m different inputs to produce s different outputs. If the model supposes constant returns to scale (CRS), the so-called CCR model can be used [11]. The output-oriented CCR model is formulated as follows:

$$\min \; q = \sum_{i=1}^{m} v_i x_{io} \tag{1}$$

subjected to

$$\begin{gathered} \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} + q_0 \geq 0 \\ \sum_{r=1}^{s} \mu_r y_{ro} = 1 \\ \mu_r, v_i \geq 0 \; \varepsilon > 0 \end{gathered} \tag{2}$$

where x_{ij} is the amount of input i of DMU_j, y_{rj} is the amount of output r of DMU_j, v_i and μ_r are weights of inputs and outputs, and ε is a so-called non-Archimedian element. DMU is 100% efficient if $q = 1$, i.e. there is no other DMU that produces more outputs with the same combination of inputs. On the other hand, DMU is inefficient if $q \geq 1$.

If the model supposes variable return to scales (VRS), the so-called BCC model can be used [12]. The output-oriented BCC model is then formulated similarly as the CCR model, but requires constraint $\sum_{j=1}^{n} \lambda_j = 1$. This added constraint introduces an additional variable μ_0 into the model. This extra variable enables to express variable returns to scale [13].

Data

The analysis includes the 30-best coffee producing countries that are evaluated worldwide: Brazil, Vietnam, Colombia, Indonesia, Ethiopia, Honduras, India, Uganda, Mexico, Guatemala, Peru, Nicaragua, China Ivory Coast, Costa Rica, Kenya, Papua New Guinea, Tanzania, El Salvador, Ecuador, Cameroon, Laos, Madagascar, Gabon, Thailand, Venezuela, Dominican Republic, Haiti, Democratic Republic of Congo and Rwanda.

These countries are evaluated according to the following variables:

- *Production cost per hectare*: This variable allows us to know with precision the cost of production per hectare. This data in crucial for the analysis as it is based on both economic and productive performance.
- *Pounds per year*: Production per year that a country produces.

- *Area of cultivation*: The area of cultivation is the area of the total land of the country which is only occupied for the harvesting of coffee.
- *GDP per capita*: Gross Domestic Product (GDP) per capita is the income of productivity, goods, services and economic development that each person or each inhabitant has based on the results of the year 2017.

The data were obtained from several sources. *GDP per capita* for each country (in 2017) and data related to *Area of cultivation* (2015) were obtained from the World Bank [14]. The *pounds per year* variable was obtained from World Atlas [2], and, finally, the *Production cost per hectare* were searched in the official website of International Coffee Organization (ICO) [15]. Table IV in the appendix summarizes the obtained data for all 30 countries.

Structure of the model

The DEA model is an output-oriented as we seek to analyze how efficient is the coffee production in each country measured by its coffee production in pounds. Further, the DEA model operates under constant returns to scale (CCR model) as each country operates separately on its own territory. To measure this, Production cost per hectare, Area of cultivation and GDP per capita are inputs, whereas Pounds per year is the only output in the analysis. For the calculations we use MaxDEA software.

III. Results

In this section, we present the achieved results of the coffee production analysis. First, we justify the DEA model structure and, second, we will present the results for all 30 countries.

Table III displays the weight of each input and output for the productivity analysis. As there is only one output, *Pound per year* must have 100% importance. On the other hand, the importance of inputs varies. The average weights for *GDP per capita* is 44.72% and for *Production cost per hectare* 41.22%. These two inputs explain the model by 83.94%. The last input (*Area of cultivation*) has its weight 14.06%, which is significantly below the first two inputs. However, the weight is sufficient to keep this variable in the mode. Therefore, we can conclude that the model structure is well-constructed.

The results of the analysis are shown in Table V in the appendix. There are only three countries with 100% efficiency in the coffee production: Brazil, Vietnam and Colombia. These countries are also the three biggest coffee producers and exporters. Although their size of production, these countries were able to maintain their production efficient. If we look closer to the preference use of the inputs (Table III), we can see that Brazil benefits from its lower level of GDP per capita (importance 72.78%) and Area of cultivation (24.91%). In the absolute numbers the Brazilian's area of cultivation is very big. However, in relative numbers the area is not very big as most of the country is covered by the Amazonian jungle. Similarly, Colombia benefits from its lower level of GDP per capita (85.34%) and, contrary to Brazil, from lower production cost per hectare (14.38%). On the other hand, Vietnam reached the 100% efficiency due to very low production cost per hectare (94.04%).

The rest of the countries are not 100% efficient. The average efficiency is 22.631% with SD 30.115%. Only three other countries are above this average: Indonesia (58.541%), Ethiopia (30.718%) and Honduras (61.469%). Further, we can observe that the worst countries are Dominican Republic (0.877%), Haiti (0.825%) and Rwanda (0.465%). As we can see, Mexico reached the efficiency of 14.907%, which is relatively bad and also below the average.

With the projection analysis included in Table V, we can analyze the necessary changes for each country to reach the 100% efficiency. For example, Mexico currently produces 515,881,000 pounds of coffee per year (Table IV). However, to become 100% efficient, Mexico should produce 3,453,173,203 pounds of coffee per year. It means that the Mexican's coffee production should increase approximately 6.7 times. Similarly, we can analyze the projection of Costa Rica, which is geographically close to Mexico, but its efficiency is only 6.848%. Costa Rica currently produces 197,357,000 pounds of coffee per year. To become the efficient country, Costa Rica should increase its production 14.58 times up to 2,876,88,220 pounds per year.

TABLE III
WEIGHT DISTRIBUTION FOR INPUTS AND OUTPUTS (OWN CALCULATION)

Country	GDP per capita	Production cost per hectare	Area of cultivation	Pounds per year
Brazil	72.78%	2.31%	24.91%	100.00%
Vietnam	1.66%	94.04%	4.30%	100.00%
Colombia	85.34%	14.38%	0.29%	100.00%
Indonesia	41.09%	57.47%	1.45%	100.00%
Ethiopia	13.44%	0.88%	85.69%	100.00%
Honduras	52.35%	46.59%	1.06%	100.00%
India	8.89%	0.84%	90.27%	100.00%
Uganda	5.54%	0.69%	93.76%	100.00%
Mexico	67.22%	32.44%	0.33%	100.00%
Guatemala	58.10%	0.25%	41.65%	100.00%
Peru	80.11%	19.77%	0.12%	100.00%
Nicaragua	48.16%	51.24%	0.60%	100.00%
China	63.57%	36.25%	0.18%	100.00%
Ivory Coast	61.68%	37.90%	0.42%	100.00%
Costa Rica	0.68%	99.26%	0.06%	100.00%
Kenya	59.81%	39.98%	0.21%	100.00%
Papua New Guinea	83.73%	16.25%	0.02%	100.00%
Tanzania	27.98%	71.79%	0.23%	100.00%
El Salvador	25.11%	74.78%	0.10%	100.00%
Ecuador	53.84%	46.13%	0.03%	100.00%
Cameroon	36.66%	63.22%	0.13%	100.00%
Laos	67.04%	32.93%	0.02%	100.00%
Madagascar	67.22%	0.33%	32.45%	100.00%
Gabon	0.19%	99.80%	0.01%	100.00%
Thailand	67.22%	32.61%	0.17%	100.00%
Venezuela	84.47%	15.51%	0.02%	100.00%
Dominican Republic	56.57%	0.03%	43.40%	100.00%
Haiti	5.18%	94.76%	0.06%	100.00%
Democratic Republic of the Congo	41.82%	58.12%	0.06%	100.00%
Rwanda	4.04%	95.92%	0.04%	100.00%
Average	44.72%	41.22%	14.06%	100.00%

Of course, these projections lie only in the theoretical dimension. An improvement of a production is a combination of many variables and processes. Considering the variable used in this article, Mexico's efficiency is related mainly to its GDP per capita and Production cost per hectare (Table III).

This means, that Mexico plants coffee in a very large area, however, the production per hectare is not sufficient. Thus, Mexico should focus on an improvement in a technological part of the production. Turning our attention to Costa Rica now, its efficiency result is completely related to Production cost per hectare. It means, that the costs in Costa Rica are really low. Similarly, as in Mexico, technological improvement is needed to increase the coffee production from each hectare. What is more, the GDP per capita shows that Costa Rica could have enough economical resources (compare to the other analyzed countries) to manage the technological improvement (such as Mexico).

IV. Discussion

The imbalance in the world coffee market and the resulting low prices were exacerbated by the new plantations registered in Vietnam, and by an increase in Brazilian exports due to the expansion of the surface planted in non-freezing areas, to the improvement of the productivity and the devaluation of the real at the beginning of 1999.The economic and social effects of the fall in coffee prices are documented in a recent FAO study in the producing countries. [16] For example, 122,000 jobs were lost in Nicaragua and 10,000 in Costa Rica. In Papua New Guinea, employment in the large-scale sector had fallen by 40%. In addition, Ivory Coast, Ethiopia, and Nicaragua pointed to fiscal constraints on the national investment budget related to the problems in the coffee market.

Considering the achieved results, we propose a strategy of 3 factors. First, it is necessary to find alternative ways of coffee cultivation, i.e. use to the maximum of the area of cultivation with a program of artificial culture technology, improve performance for harvesting despite the weather changes. Second, it is necessary to improve the level of production costs. Most of the countries must find a balance between the necessary technological improvements and production costs per hectare. With higher coffee quality and cost effectiveness, the inefficient countries can improve the coffee production from each hectare. Last but not least, we propose to make a market analysis of existing investments in harvesting, an analysis of the costs of products, machinery and jobs for sowing, harvesting and production of coffee. So, in rhetorical way, it is necessary to improve the decision-making for a favorable cost.

V. Conclusions

In this article, we analyzed productivity of the 30 biggest coffee producers in the world. For the purpose of the analysis we used Data Envelopment Analysis. We constructed CCR output-oriented DEA model including *GDP per capita*, *Production costs per hectare*, *Area of cultivating* as inputs, whereas the *Production in pounds per hectare* was the only output. The results reveal that the average efficiency of all countries was 22.631% with SD 30.115%. Brazil, Vietnam and Colombia were the only 100% efficient countries. The majority of the countries are ranked below the average, only Indonesia (58.541%), Ethiopia (30.718%) and Honduras (61.469%). Are above the average. Mexico belongs among the inefficient countries, as its efficiency is only 14.907%. The data indicates that Mexico should increase its coffee production by 6.69 times or increase the production potential from each cultivated hectare.

Our comparison study helps us to understand the productivity of the coffee production. However, it is necessary to say, that the analysis was based only on the data from 2017. For deeper and more complex results, it is necessary to extend the analysis for more years. This extension would allow us to see efficiency trends in the sector for all 30 analyzed countries. Similarly, the analysis would be extended for more countries, as there are approximately 80 coffee producers around the world. Last but not least, an econometric analysis can be used to precisely analyze the effect of each variable (and other variables) on the coffee production. This all can be a part of a future research.

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APPENDIX

TABLE IV
DATA OF THE 30 BEST COUNTRIES COFFEE PRODUCERS

Country	GDP per capita	Production cost per hectare	Area of cultivation	Pounds per year	Surface
Brazil	7744.53446	$ 8,100,000.00	0.096	5,710,381,000	8 515 000
Vietnam	130.67242	$ 13,450,000.00	0.226	3,637,627,000	331 200
Colombia	5066.53981	$ 621,000.00	0.015	1,785,744,000	1 140 000
Indonesia	3393.91559	$ 3,450,000.00	0.13	1,455,050,000	1 900 000
Ethiopia	684.488545	$ 10,000,000.00	0.151	846,575,000	1 104 000
Honduras	2169.77364	$ 1,400,000.00	0.091	767,208,000	112 100
India	1499.07412	$ 35,000,000.00	0.526	767,208,000	3 290 000
Uganda	588.903485	$ 22,000,000.00	0.344	634,931,000	236 000
Mexico	7723.80403	$ 2,700,000.00	0.118	515,881,000	1 970 000
Guatemala	3521.25609	$ 6,262,000.00	0.087	449,743,000	108 889
Peru	5489.47548	$ 980,670.00	0.032	423,287,000	1 285 000
Nicaragua	1849.86844	$ 1,424,207.00	0.125	291,010,000	121 430
China	7271.45134	$ 3,000,100.00	0.127	257,544,000	9 600 000
Ivory Coast	1315.97918	$ 1,400,340.00	0.091	238,099,000	322 500
Costa Rica	10439.1365	$ 1,000,450.00	0.045	197,357,000	51 100
Kenya	1332.41322	$ 1,540,000.00	0.102	110,187,000	580 367
Papua New Guinea	2140.29536	$ 300,454.00	0.007	105,821,000	246 000
Tanzania	811.655135	$ 3,600,000.00	0.152	105,821,000	945 000
El Salvador	3644.43775	$ 18,760,000.00	0.362	100,795,000	21 040
Ecuador	5228.59323	$ 3,240,000.00	0.043	92,594,000	255 000
Cameroon	1198.03325	$ 3,570,000.00	0.131	75,398,000	475 500
Laos	2111.14374	$ 750,000.00	0.018	68,784,000	236 800
Madagascar	361.834201	$ 4,890,000.00	0.006	68,784,000	587 000
Gabon	4581.643	$ 530,000.00	0.013	66,138,000	267 700
Thailand	5416.27767	$ 1,900,000.00	0.329	66,138,000	513 100
Venezuela	6702.05479	$ 890,000.00	0.031	66,138,000	915 000
Dominican Republic	6301.09098	$ 12,320,000.00	0.166	52,910,000	47 900
Haiti	633.347621	$ 20,000,000.00	0.388	46,297,000	27 065
Democratic Republic of the Congo	370.765409	$ 890,000.00	0.031	44,312,000	2 345 000
Rwanda	625.878699	$ 25,674,000.00	0.467	33,069,000	26 800

TABLE V
RESULTS OF THE PERFORMANCE ANALYSIS AND RELATED INPUT AND OUTPUT PROJECTIONS (OWN CALCULATION)

Country	Score	Projection (GDP per Cap)	Projection (Production costs per hectare)	Projection (Area of cultivation)	Projection (pounds per year)
Brazil	100.000%	7,744.534	8,100,000.000	0.096	5,710,381,000
Vietnam	100.000%	130.672	13,450,000.000	0.226	3,637,627,000
Colombia	100.000%	5,066.540	621,000.000	0.015	1,785,744,000
Indonesia	58.541%	3,393.916	3,450,000.000	0.041	2,460,924,807
Ethiopia	30.718%	684.489	9,171,873.365	0.151	2,753,946,506
Honduras	61.469%	2,169.774	1,400,000.000	0.018	1,237,478,624
India	8.412%	1,499.074	31,674,900.530	0.526	9,113,643,355
Uganda	11.041%	588.903	20,593,626.190	0.344	5,748,186,508
Mexico	14.907%	7,723.804	2,700,000.000	0.041	3,453,173,203
Guatemala	13.709%	3,521.256	6,255,061.924	0.087	3,280,562,371
Peru	20.507%	5,489.475	980,670.000	0.019	2,063,128,957
Nicaragua	25.150%	1,849.868	1,424,207.000	0.018	1,151,160,584
China	7.474%	7,271.451	3,000,100.000	0.043	3,441,944,453
Ivory Coast	24.294%	1,315.979	1,400,340.000	0.017	976,701,423
Costa Rica	6.848%	8,162.351	1,000,450.000	0.024	2,876,888,220
Kenya	10.770%	1,332.413	1,540,000.000	0.019	1,021,395,778
Papua New Guinea	13.738%	2,140.295	300,454.000	0.007	770,255,157
Tanzania	7.944%	811.655	3,600,000.000	0.056	1,330,244,373
El Salvador	1.512%	3,644.438	18,760,000.000	0.297	6,663,368,505
Ecuador	3.164%	5,228.593	3,240,000.000	0.042	2,926,297,182
Cameroon	5.024%	1,198.033	3,570,000.000	0.054	1,499,666,052
Laos	7.248%	2,111.144	750,000.000	0.011	948,860,627
Madagascar	23.591%	361.834	468,318.549	0.006	290,702,741
Gabon	4.339%	4,324.100	530,000.000	0.013	1,524,064,928
Thailand	2.724%	5,416.278	1,900,000.000	0.029	2,424,287,275
Venezuela	2.766%	6,702.055	890,000.000	0.021	2,390,764,015
Dominican Republic	0.877%	6,301.091	11,805,311.350	0.166	6,033,232,383
Haiti	0.825%	633.348	20,000,000.000	0.334	5,610,691,094
Democratic Republic of the Congo	10.884%	370.765	890,000.000	0.013	406,968,487
Rwanda	0.465%	625.879	25,674,000.000	0.429	7,116,516,331
Average	22.631%				