VOL. 17, NO. 17, SEPTEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IDENTIFICATION OF THE RELATIONSHIP BETWEEN ECONOMIC AND SOCIAL GROWTH AND ENERGY DEVELOPMENT IN COLOMBIA, THROUGH MULTIVARIATE PICTORIAL GRAPHS AND DISPERSION MATRIX

Jaime Alejandro Ospina Betancur[1], Jhony Mauricio Gutierrez Florez[2], Lester Dario Portillo Jimenez[1] and Juan Gonzalo Ardila Marín[3]
[1]Fundación Universitaria Autónoma de las Américas, Medellín, Colombia
[2]Institución Universitaria Pascual Bravo, Medellín, Colombia
[3]Area of Agricultural Machinery, Agricultural Engineering, Universidad Surcolombiana, Neiva, Colombia
E-Mail: juan.ardila@usco.edu.co

ABSTRACT

Colombia is a country with a great projection in its energy development. It would be important to identify the relationship between economic and social growth and energy development with different potential countries of the world such as the United States, Canada, Russia, and with other countries such as Brazil, which in South America make a difference, thus generating a prospective vision in order to improve the socio-economic-energy condition of Colombia. In this work a series of countries are analyzed by their energy characteristics which are: Colombia, Venezuela, Mexico, Brazil, Argentina, United States, Canada, Russia, Iraq, Iran and China; in order to carry out an analysis between the economic, energy and social relationship; For this, the variables to be analyzed are defined, they are specified by their economic importance (GDP, GDP per capita and inflation), social (human development index-HDI) and energy (oil, gas and electricity production); The data is collected and standardized to proceed with the simulation of the Chernoff graphs, Stars and the relationship matrix between the different analysis variables, which allows an analysis of the current state of growth economic, social and energy development and its possible projections. According to the graph, it is concluded that Colombia is like Mexico and China if the population variable is also added to the latter. The face of the simulation with the greatest representation of the variables is that of the United States, which has greater homogeneity in its variables, being the one with the greatest development. According to the Chernoff graphs, which represent each country and each of the variables to be studied represents a physiological characteristic of the face; it is possible to identify the similarities between the countries in relation to these variables. Giving rise to the analysis of the socio-economic situation and energy production of the countries that is similar.

Keywords: techno-economic analysis, indicators graphical analysis, economic development, developing countries.

INTRODUCTION

Through the Chernoff and star graphs, we seek to identify similar characteristics in relation to the variables analyzed. According to the facial features produced by the simulation, it is possible to identify the similarity according to inflation, the Human Development Index (HDI), total and per capita GDP, oil production, natural gas production and electricity production. According to (Honty, 2005) in 1980, a total of 247 Mtoe (million tons of oil equivalent) were consumed in Latin America. By 2004, consumption had risen to 483 Mtoe, half of which was oil. A practically direct relationship between growth in the energy sector and development is common. Thus, investments in the sector have been justified by the need to generate employment, provide energy services to most of the population, and generate wealth for society. However, the Latin American history of the last 25 years shows that energy consumption has doubled without having made much progress in reducing poverty.

For (Honty, 2005) there is not, in the recent history of the region, a direct relationship between energy and social indicators. This situation could have been corrected by internalizing other values when deciding on energy projects: observing which sectors of the economy the new consumption was aimed at, how its product would be distributed in society, who would be the most favored. For example, an energy investment that affects the public transport sector for people will have greater effects on low-income sectors than one related to the aluminum industry (Rosenberg, 1998). In the first case, the relationship is direct (investment-beneficiary) while in the second it is indirect (investment-job-beneficiary) but also has a low occupancy rate in relation to the energy consumed.

According to (Honty, 2005) another associated indicator is energy efficiency. In Latin America, energy consumption increases when the economy grows, but does not fall in the same proportion when there is a recession. According to Cepal, the trend of energy consumption is always increasing, even when the economy does not grow. Today 7% more energy is consumed than in 1980 to generate the same unit of product, which shows that the region has lost degrees of energy efficiency (Cepal, 2002).

Consequently, in the foregoing, historically there are no data on the economic-energy relationship of some Latin American countries in relation to the main exporters of energy production.

kTrends in the use of a certain type of energy are determined by technological advances to obtain new sources or to improve those already available, based on

ARPN Journal of Engineering and Applied Sciences

parameters of abundance, efficiency, costs and, more recently, environmental aspects.

In this work a series of countries are analyzed by their energy characteristics, to carry out an analysis between the economic, energy and social relationship. For this, the variables to be analyzed are defined; they are specified by their economic importance (GDP, GDP per capita and inflation), social (human development index-HDI) and energy (oil, gas, and electricity production). The data is collected and standardized to proceed with the simulation of the Chernoff graphs, Stars, and the relationship matrix between the different analysis variables, which allows an analysis of the current state of growth economic, social and energy development and its possible projections.

LITERATURE REVIEW

In the past three centuries, industrialized economies have shifted from a near total dependence on biomass fuels (such as wood) to coal and later to oil and natural gas. However, these changes have occurred only in the face of accessibility to sources and means of use (Peet, 2004). (Fouquet, 2009) It amplifies this change described by (Peet, 2004), showing that until 1850 almost all the energy consumed was derived from wood; but, in 1910, most of the energy consumption was coal. And then in 1970, oil and natural gas became most of the energy consumed. (M.A. Toman, 2003), based on (D.F. Banes, 1996), claim that there is an "energy ladder." This ladder represents a link between energy and other inputs of economic activity that changes significantly according to the technological-economic advance through the different stages of development. According to (Mensah, 2013) in this modern era, energy has become the bloodline of most economies as it powers all sectors of the economy. Production, distribution and consumption of goods and services are developed largely from energy. Thus, energy is considered as a key engine of growth, industrialization, and urbanization (Esso, 2010).

According to (N. Apergis, 2010) one of the fundamental interrelationships between energy and the economic system is the tri-variable relationship that exists between energy consumption, production growth and carbon dioxide emissions. The interrelationships between these three variables are often complex, due to the dynamics of the feedback effects that exist between them. In the literature, for example, four main hypotheses have been documented on the nexus between energy consumption and economic growth, namely: energy-led growth, conservation (consumption of energy-led growth), feedback and the neutrality hypothesis (Esso, 2010). The energy-driven growth hypothesis postulates a one-way causality ranging from energy consumption to growth without feedback effects: implying that conservation policies are enemies of growth. However, the conservation hypothesis states that energy saving does not necessarily imply growth retardation, since the direction of causality goes from the growth of energy consumption. Rather, the feedback hypothesis refers to energy and growth as complementary factors that exert significant influences on each other. However, the view of neutrality does not accept any type of interrelationships between energy demand and production growth, but sees them as two exogenous forces (Esso, 2010).

For (Vera, 2007) by reducing the amount of energy consumed without sacrificing socio-economic growth, improvements in energy efficiency translate into progress towards sustainable development since investments in energy infrastructure and spending on costs Fuel costs can be reduced, as well as environmental impacts. Efficiency improvements can be achieved by changes in energy-related technologies and processes. Improvements in energy intensity are made through increased energy efficiency and through changes in economic structures, fuel mix and consumer behavior.

In its 2007 edition of World Economic Outlook (IMF, 2007), the International Monetary Fund analyzes the link between oil prices and the world economy, distinguishing two cases, that is, the "supply" in the face of oil shocks. Oil prices and induced "demand". According to predictions by the (IEA, 2008) of future oil demand, they have always been guided by the connection between economic growth and increased oil consumption.

According to a study carried out by (Amir B. Ferreira Neto, 2014) on *the comparison of energy consumption structures: an input and output decomposition analysis of large economies based on developing economies* such as Brazil, China and India and the developed economies of Germany, the United Kingdom and the United States for the years 1995 and 2005, there is an exponential increase in GDP per capita in the sample period for China and India, and a more stable and smaller increase for the other countries. In terms of final energy use per capita, as of 2000, there is a clear difference between developed and developing countries. While the former is decreasing energy use, the latter are constantly increasing.

For this case (Amir B. Ferreira Neto, 2014, p. 167) affirms that developing countries are growing and in some cases at higher rates than in developed countries. And they are posing their per capita energy use differently than developed countries, because as they grow, they become more open to trade and therefore more important internationally. (J.H. Brown, 2011). They claim that countries with more developed economies have advantages of scale due to the quantity and quality of their available infrastructures. The authors also show that these countries have the new technologies related to the most efficient use of energy per capita that affect their GDP per capita. This effect allows the authors to confirm the discrepancy between developing and developed countries. Therefore, developed countries with an established production structure must use a different and more efficient mix of energy inputs in each sector of developing countries. On the other hand, as developing countries grow and improve their production structure, the combination of energy inputs could be like those of developed countries.

(Fouquet, R., 2010). Analyze how societies use renewable energy and maintain economic growth throughout history. The author notes that this use of energy could impose limitations. For the author, economic growth is interconnected with the energy debate due to the availability, extraction, transmission and use of energy. As new technologies are developed and made available, transitional periods between economic stages of development can increase speed. However, technology is based on infrastructure, that is, capital goods, so there is no access to new energy sources (Fouquet, 2009) and (M.A. Toman, 2003).

In a recent study by the Fraser Institute, which posits Canada as an emerging energy super producer, Dr. Kenneth P. Green of the Fraser Institute (Senior Director of Natural Resources Studies) and Gerry Angevine explain that although Canada is not in On the verge of becoming or trying to be an energy superpower, the country is clearly on the point of becoming a super producer of crude oil, natural gas, uranium and electricity and bound to soon become one of the world's largest exporters of these important energy products (Kenneth P. Green, 2013).

The search for rapid economic growth in emerging economies has caused an increase in energy consumption, according to (Honty, 2005) in 1980, a total of 247 Mtoe (million tons of oil equivalent) were consumed in Latin America. By 2004, consumption had risen to 483 Mtoe, half of which was oil. A practically direct relationship between growth in the energy sector and development is common. Thus, investments in the sector have been justified by the need to generate employment, provide energy services to most of the population and generate wealth for society. However, the Latin American history of the last 25 years shows that energy consumption has doubled without having made much progress in reducing poverty. According to (Honty, 2005) there is no direct relationship between energy and social indicators in the recent history of the region.

Industries have had different levels of energy consumption and employment depending on the branch. A study on Brazil (Berman) shows that while branches such as metallurgy have an employment level of six workers per toe / year (ton of oil equivalent per year), textiles can employ 248 people for each toe / year (ton equivalent of oil per year) of energy consumed. Therefore, the incidence of increased energy consumption and employment depends, even within the industrial sector, on the branch to which it is applied. According to (Honty, 2005) another associated indicator is energy efficiency.

In Latin America, energy consumption increases when the economy grows, but does not fall in the same proportion when there is a recession. So, the trend of energy consumption is always increasing, even when the economy does not grow. According to (Cepal, 2002), today 7% more energy is consumed than in 1980 to generate the same unit of product, which shows that the region has lost degrees of energy efficiency. Therefore, the incidence of increased energy consumption and employment depends, even within the industrial sector, on the branch to which it is applied. Giving support to what was stated by Honty in 2005, since although energy consumption has increased, this does not translate into social development or job creation. High economic growth generates higher energy consumption, which does not happen when the economy is in recession, since consumption remains at the same levels and may even increase, and when the economy is in recession, unemployment increases.

Technological progress, in relation to the use of energy, (Cohen, 2005) also affirms that the improvement in production processes allows developing countries to follow a less energy-intensive path than that traveled by developed countries. For (C.-Y. Ho, 2007), structural changes in the economy affect the relationship between energy and GDP, given the different nature of energy use in productive sectors. Thus, with the enrichment of an economy and its transition to a service-based economy, the higher the levels of income and savings. This higher stage in turn consumes more durable goods, which then increases energy consumption. According to (Jorgenson, 1984), technological progress leads to better forms of energy, such as electricity, which is the "greatest" refinement.

The author also claims that electricity was important to the advancement of the technology industry. The main characteristic of the transformation in the manufacturing process, with the greater use of electricity, was the redesign of the entire production system (Berndt, 1990) and (Schurr, 1984), analyzing the role of electricity in the technological progress, states that at the beginning of the 20th century, the favorable conditions in the supply of energy, as well as the abundance of available energy, the growth of the use of electricity and liquid fuels and the competitive market, reduced their prices and facilitated the propagation of energy. These favorable circumstances would encourage technological development that otherwise would probably not have occurred.

The (IEA, 2008) in a study finds the following global results regarding energy consumption: i) an increase of 23% in the use of energy from 1990-2005 of the member countries of the Organization for the Economic Cooperation and Development (OECD), while the increase in non-member countries was greater; ii) oil continues to be the end-use of energy commodities with the largest share; iii) biomass and coal remain important in non-OECD countries, but have been losing ground to other inputs; iv) the decrease in energy intensity was greater in non-OECD countries, and the main factors due to structural changes and efficiency; v) between 1990 and 2005, household consumption increased by 22% in OECD countries and 18% in non-member countries; vi) the share of non-renewable energy in the mix of inputs consumed by OECD countries is increasing; and vii) in non-member countries, renewable sources have the largest share and also the fastest growing.

According to the fundamental question proposed by (Pao, 2005), who found that Taiwan's energy consumption has increased considerably due to rapid economic growth and better living standards. According to studies carried out by (Hamilton, 1996), (K.A. Mork, 1994) and (Balke NS, 1999), they argue that there is a linear relationship between oil and the economy.

According to (J. Moral-Carcedoa, 2005) the need for energy is a key factor in the production process, which is linked to economic activity and development, such as the use of electricity.

(J. Darmstadter, 1977) They affirm that the energy used in the production process is one of the components of economic growth. The returns from this growth and the increased revenue provided allow for increased energy consumption associated with the creation of convenience and other services.

This fact is what (Rosenberg, 1998) associates with the creation of human well-being from the improvement of electrical services. In the same sense, (MA Toman, 2003), in the case of developing countries, they affirm that the growth of energy use and greater access to energy have positive effects on factor productivity, due to the improvement of human capital, such as education, housing and health, among others.

According to (J. Zhao, 2007) they conclude that the relationship between energy consumption and economic growth varies according to countries or regions, and even during different phases due to the changing priorities given to energy and economic policies during economic development.

According to (Contreras, 2014) the energy sector has always been one of the most important for the development of a country. Since the 90s, and specifically since 1993 with the enactment of the so-called Electric Law, the Colombian electric power industry has undergone constant changes that allow it to be considered today one of the most modern and developed industries not only in the country, but from all Latin America. According to (ER Larsen, 2004).

METHODOLOGICAL DESIGN

The research methodology used in the development of this project is based on the analysis with multivariate pictorial graphics.

Analysis with Multivariate Graphs

There are different articles that argue about the importance of adding depth to an essentially 2D graphic as this is the style preferred by most newspapers and businesses. In addition, they argue that there is nothing wrong with beautifying graphics to grab people's attention. On the other hand, they argue about the importance of not degrading readers by assuming they won't take the time to look at the data. As with writing, keep graphics simple, and your audience will get your message.

Now Herman Chernoff argues that human beings can discern subtle differences in facial expressions (Chernoff, 1973). Indeed, if multivariate data are represented by a facial expression, it could be easier to compare data sets (Matos, 2010).

Chernoff Charts

Basically, Chernoff face graphs are a multivariate data representation method, where each point in k-dimensional space is represented by a drawing of a face whose characteristics, such as the height of the nose and the curvature of the nose. Mouth, correspond to the components of the point. In other words, Chernoff's faces are a series of 2D shapes and lines that mimic facial features, i.e., a triangle for a nose, a circle for an eye, etc. (Fukumori, An Application of Statistical Graphs to Cluster Analysis., 1990). Given the above, each multivariate observation is visualized as a computer-drawn face. This presentation makes it easy for the human mind to understand many of the regularities and irregularities present in essential data. Other graphic representations are briefly described (Chernoff, 1973). In this sense, there are different studies in the academic literature that use Chernoff's faces in multivariate analysis in different areas of knowledge such as marketing (Pitt, 2011), product design (Garneau, s.f.), cluster analysis (Fukumori, An Application of Statistical Graphs to Cluster Analysis., 1990) (Fukumori, Evaluation of multivariate graphs., 1995), among other applications.

Star Graphics

Star Plots (Chambers, 1983) are a method to represent multivariate data that are not very numerous where gi is a star. All conventional statistical software usually includes this multivariate representation technique (R, STATGRAPHIS, SPSS ...). A star, which represents an element of the sample or population, is defined from a set of radii, which form the same angle, and which converge at a geometric center. Each radius represents a variable. Its length is proportional to the magnitude of the represented variable, relativized to the maximum value that it reaches in the population. The line connecting the ends of the radii determines the star chart. In general, the radii are not drawn, only the outline is specified (Chambers, 1983).

Dispersion Matrix

Sparse matrices are widely used in scientific computing, especially in large-scale optimization, structural and circuit analysis, computational fluid dynamics, and in general in numerical solution of partial differential equations; other areas of interest where sparse representation can be applied are graph theory, network theory, combinatorics, numerical methods, among others. Given its frequent appearance, there are multiple software packages that allow its implementation and operation, such as Sparspak, the Yale Sparse Matrix package, some routines from the Harwell subroutine library, in addition to the Matlab software package, R Estudio among others. Since these types of matrices occur so naturally over the years, different methods have been developed to represent them on a computer, so that they are more efficient in their computation and storage (Mejía Soto &Solarte, 2013)

Through this documentary-type study, it is intended to make a multivariate analysis by means of pictorial graphs. Given the above, multivariate statistical graphs are used for the study to determine clusters, standards and trends among the countries analyzed. For the study, data from 11 countries (n = 11) were used, in which social variables such as HDI were studied; an economic variable such as total GDP and GDP per capita and inflation; and oil, natural gas and electricity production variables.

Once the database is built, the data are standardized and later, using the free R statistical software, the Chernoff face graphs and star graphs are constructed. Once the above is finished, a comparative analysis is carried out that allows the construction of clusters and trends between the countries.

On the other hand, the availability of efficient statistical software such as R suggests complementing the indispensable strategies of exploratory analysis of the information with graphical representations appropriate to the multidimensional context that can help to achieve a better understanding of the problem of interest.

The graphic synthesis formed by the application of multivariate statistical graphics to determine clusters, standards, and trends between countries and that complements the knowledge in this aspect of the international reality, can suggest some hypotheses, object to others, and help in the interpretation of complex results. Certainly, this is extensible to many other situations of interest to the researcher of economic and administrative areas (Cienfuegos, 2013) and (Oksanen, 2011).

Now, for the construction of the graphs it is necessary to standardize the variables, since they are all measured in different units such as US $%, dimensionless, among others. Given the above, the (1) is used.

$$Standardized\ Value = \frac{(X_i - \underline{X})}{\sigma_i} \quad (1)$$

Subsequently, with the variables already standardized, the multivariate graphs can be constructed and the analyzes set out in the research objectives can be carried out; that is, to determine clusters, standards and trends among the countries examined.

Human Development Index (HDI)

The Human Development Index (HDI) aims to measure capabilities, the set of options available to a person and, ultimately, the freedoms they enjoy. The HDI has four components, namely life expectancy at birth, the adult literacy rate, the combined enrollment rate in primary, secondary, and tertiary education, and real income measured in terms of purchasing power parity (Griffin, 2001).

The Human Development Index can also be adjusted to incorporate a gender perspective. UNDP has developed a “gender-sensitive” HDI capable of reflecting differences between women and men in areas such as life expectancy, literacy, and income. Therefore, the HDI is a flexible instrument capable of measuring differences between countries in their level of human development and changes in human development over time; it also makes it possible to measure the impact of inequality in income distribution and discrimination against women in human development (Griffin, 2001).

Gross Domestic Product (GDP)

GDP represents the result of the productive activity of resident production units. It is measured from the point of view of added value, final demand or final uses of goods and services, and primary income distributed by resident production units (DANE, s.f.).

GDP Per Capita

The total value of the current production of final goods and services within the national territory during a certain period, divided by the value of the total population, is called per capita product (Restrepo, s.f.).

Inflation

It is an imbalance between the supply of products and services and the amount of money available at any given time to demand or buy those goods, which tend to be scarce (Banrep, s.f.).

RESULTS

To carry out the comparative analysis between countries, the HDI, total GDP and GDP per capita and inflation are jointly studied; and the variables of oil, natural gas, and electricity production. Table-1 shows database with indicators from 11 countries.

ARPN Journal of Engineering and Applied Sciences

Table-1. Database with indicators from 11 countries.

COUNTRY	P.OIL	P.GAS	P.ELE	INF	HDI	GDP	GDP per capita
COLOMBIA	930,03	10,96	61.820.000.000	2,20%	0,719	369.813	7.752
USA	7841,26	651,29	4.099.000.000.000	1,50%	0,937	16.244.600	51.163
CANADA	3521,6	160,48	618.900.000.000	1,00%	0,911	1.821.445	52.283
BRAZIL	2.192,91	16,7	530.700.000.000	6,2%	0,730	2.254.109	11.347
RUSSIA	10.280,33	607,01	1.057.000.000.000	6,80%	0,788	2.029.812	14.178
IRAQ	2798,11	1,85	47.400.000.000	2,00%	0,59	149.370	4.557
CHINA	4.089,66	102,53	4.977.000.000.000	2,60%	0,699	8.358.400	6.070
MEXICO	2937,78	52,47	296.000.000.000	4,00%	0,775	1.183.655	9.795
VENEZUELA	2720,3	31,8	127.600.000.000	56,20%	0,748	382.424	12.767
IRAN	4321,1	151,8	239.700.000.000	42,30%	0,742	342.424	7.217
ARGENTINA	606,87	39,79	119.300.000.000	20,80%	0,811	204.681	11.610
AVERAGE	3839,995455	166,0618182	1.106.765.454.545	0,132363636	0,768181818	3030975,727	17158,09091
Median	2937,78	52,47	296.000.000.000	0,04	0,748	1183655	11347
STANDARD DEVIATION	2875,244724	235,4479757	1,73383E+12	0,189015488	0,096267147	4970706,611	17337,97562

Source: (Instituto Brasileiro de Geografía e Estatística, 2013).

After standardizing the values with formula (1), Table-2 is obtained, with which the different variables are assigned to the parts of the face, as shown in Table-3.

Table-2. Standardized database.

COUNTRY	P.OIL	P.GAS	P.ELE	INF	HDI	GDP	GDP per capita
COLOMBIA	-1,012075748	-0,658751972	-0,602680242	-0,583886737	-0,510888913	-0,535369101	-0,542513792
USA	1,391625733	2,060872175	1,725794042	-0,62092074	1,753642719	2,658298972	1,961296395
CANADA	-0,110736819	-0,023707225	-0,281380113	-0,647373598	1,483560965	-0,243331748	2,025894479
BRAZIL	-0,572850527	-0,634372913	-0,332250134	-0,372263867	-0,396623555	-0,156288992	-0,335165479
RUSSIA	2,239925698	1,872805152	-0,028702605	-0,340520437	0,205866512	-0,201412758	-0,171882287
IRAQ	-0,362364096	-0,697444171	-0,610997087	-0,594467881	-1,850909924	-0,579717524	-0,726791362
CHINA	0,086832451	-0,269833784	2,232187222	-0,56272445	-0,718644108	1,071763974	-0,639526272
MEXICO	-0,313787361	-0,482449755	-0,467615145	-0,488656446	0,070825635	-0,371641473	-0,424679967
VENEZUELA	-0,38942614	-0,570239849	-0,564741126	2,273022011	-0,209643879	-0,532832037	-0,253264337
IRAN	0,167326468	-0,060573119	-0,500086598	1,537632537	-0,271970438	-0,540879182	-0,573370913
ARGENTINA	-1,124469659	-0,53630454	-0,569528214	0,400159609	0,444784987	-0,568590132	-0,319996465

Source: self-made.

Chernoff Face Graphics

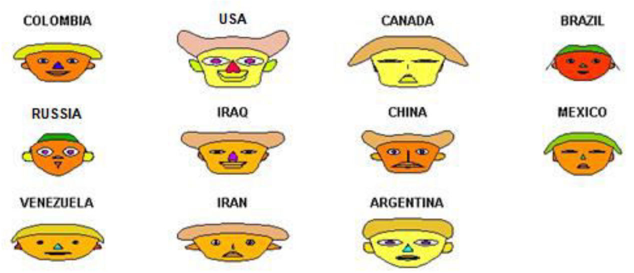
For the construction of the graphs, the assignment of variables or effects to the parts of the face is used like shown in Table-3.

Table-3. Effects of the variables.

modified item	Variable	Definition of facial features
"height of face"	"HUMAN DEVELOPMENT INDEX"	the higher the HDI, the higher the face height
"width of face"	"INFLATION"	the higher the inflation, the wider the face will be
"structure of face"	"GDP_per_capita"	the higher GDP per capita, the greater the face structure
"height of mouth"	"GPD"	the higher the GDP, the higher the mouth
"width of mouth"	"ELECTRICITY PRODUCTION"	the greater the production of electricity, the greater the length of the mouth
"smiling"	"NATURAL GAS PRODUCTION"	the higher the gas production, the more pronounced the smile will be
"height of eyes"	"OIL PRODUCTION"	the higher the oil production, the higher the eye height
"width of eyes"	"HUMAN DEVELOPMENT INDEX"	the higher the HDI, the greater the width of the eyes
"height of hair"	"INFLATION"	the higher the inflation, the higher the hair height
"width of hair"	"GDP_per_capita"	the higher GDP per capita, the wider the hair will have
"style of hair"	"GDP"	the higher the GDP, the style will be different and related to the previous trait
"height of nose"	"ELECTRICITY PRODUCTION"	the higher the production of electricity, the higher the height of the nose
"width of nose"	"NATURAL GAS PRODUCTION"	the greater the gas production, the greater the width of the nose
"width of ear"	"OIL PRODUCCION"	the wider the ears, the greater the oil production
"height of ear"	"HUMAN DEVELOPMENT INDEX"	the higher the HDI, the higher the height of the ears

Source: R studio software. Free online.

By means of the R Studio software, specifically the *aplpack* library, the Chernoff faces are constructed as evidenced in Figure-1, evidencing the usefulness of the graphical method in the comparative multivariate analysis of countries.



Source: Prepared by software R studio

Figure-1. Chernoff faces based on Table-2 Standardized variables.

Cluster 1: Colombia and Mexico

The graph shows that both countries have a low level of inflation; that of Colombia is half of Mexico; but they have an HDI almost the same, being the country that most resembles Colombia; In the case of total GDP, it shows that these countries do not have a high level for this characteristic, but since Colombia has a smaller population than Mexico, it has a higher GDP per capita.

Cluster 2: Brazil and Russia

The simulation shows faces between these two countries with similar characteristics, althoughRussia has a higher production of Oil, Gas and Electricity, but it has similarities in inflation, GDP, and GDP per capita and the HDI.

The only big noticeable facial difference is the eyes, and these are related to oil production which is much higher in Russia than in the Brazilian country. Another factor that marks their similarity is that both are members of the BRIC bloc.

Cluster 3: Iraq, Iran, and Venezuela

Iran is the country with the most energy production in the third conglomerate, followed by Venezuela and a little more distant is Iraq, but the latter with a better performance in the inflation indicator than the other two members of this conglomerate and a stable HDI among the three.

ARPN Journal of Engineering and Applied Sciences

Cluster 4: Canada, Argentina

These two countries have similarities in their HDI, but a marked difference in terms of their inflation, since while this for Canada is minimal, for Argentina it is much higher. Likewise, this marked difference is also reflected in the total GDP, since in the case of Canada this is greater than in Argentina.

China, together with the US, are the countries that are analyzed separately, the first has great economic development and great energy production but has a great lag in its social indicators, having 4 part of the world population makes its great GDP per capita be very tiny. For the second case, the US has the highest performance of the analyzed database and the Chernoff simulation compared to all the countries studied, yielding more pronounced facial features which represent the development of the country both at an energy and socio-economic level.

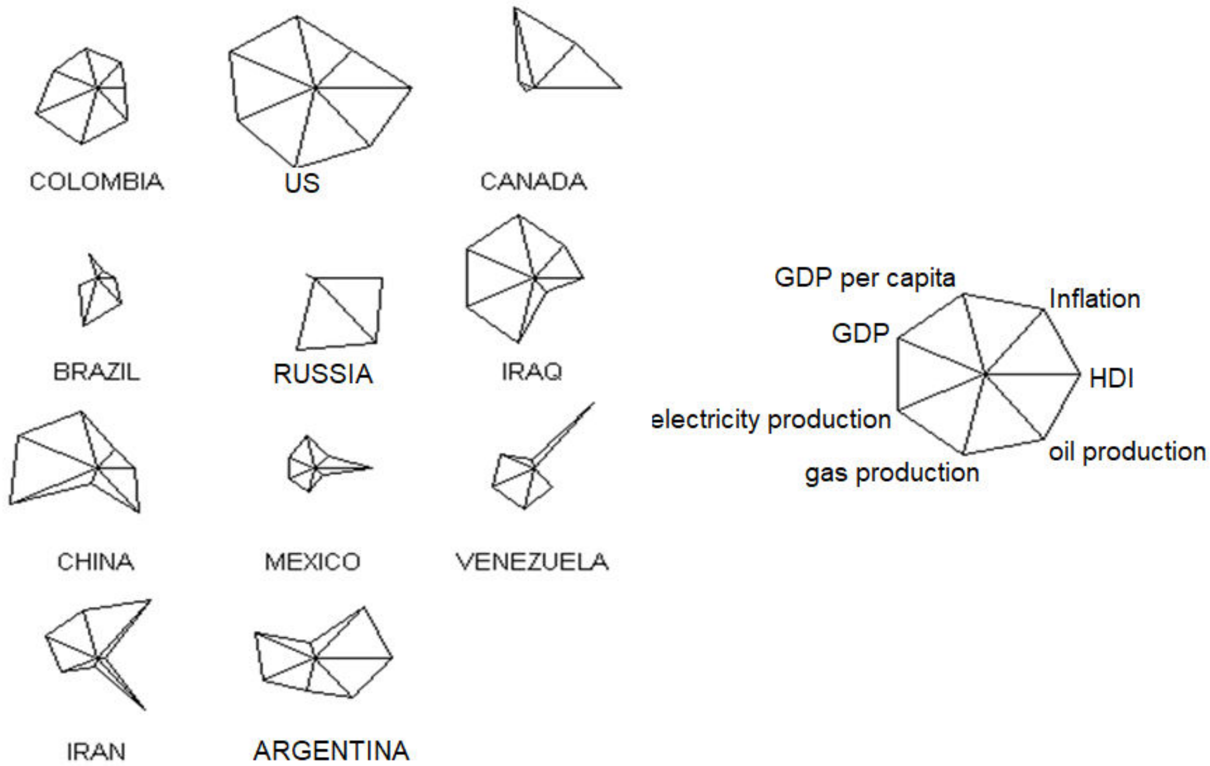
To the graph show in Figure-2, when adding the population variable to the simulation; all faces change their facial structure, which shows a similarity between Colombia and China. According to the graph, these two countries have similarities, but China, having a large energy production and a large total GDP, makes it have a facial development, but its large number of inhabitants makes its GDP per capita very small as well as its HDI and you can see in general that Colombia has a socio-economic-energy similarity with China.

Source: Prepared by software R studio.

Figure-2. Chernoff faces adding the population variable.

Star Graphics

Star charts are constructed using R studio software like show Figure-3. The star graph allows the analysis of the data according to the development of the star structure, according to the graph clearly the United States is the country with the best performance in the variables and one by one of the other countries have different development and graphic structure, and some common points of view that they try to develop through the creation and dynamization of socio-economic and energy cooperation structures (Ríos, 2004).



Source: Prepared by software R studio.

Figure-3. Star chart based on standardized variables.

The objective of Table-4 is to reduce the distance between the extreme and non-extreme economic, social and energy variables of the countries to be investigated. According to the Chernoff graph show in Figure-4, applying the natural logarithm, it shows that Colombia has an economic, social and energy growth similar to Mexico, where the higher the inflation, the higher the hair height and for this case the graph reflects a low inflation for both

VOL. 17, NO. 17, SEPTEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

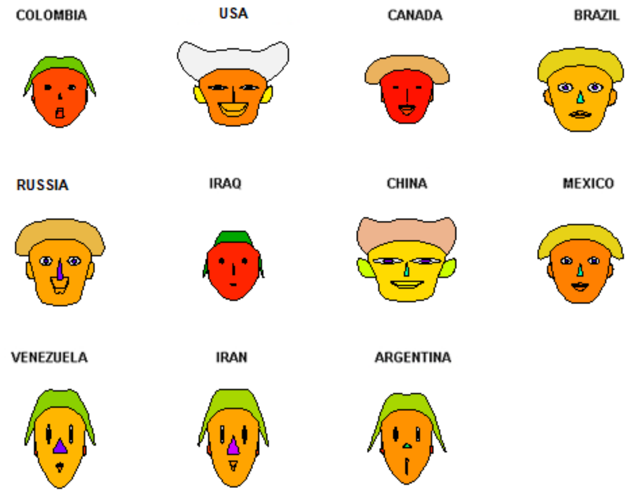
www.arpnjournals.com

countries; the higher the GDP per capita, the greater the width of the hair would be, which in this case is high for both; the higher the HDI, the greater the height of the eyes, in this case Mexico reflects a higher HDI than Colombia, without having this one very low and finally, the higher the oil production, the greater the width of the eyes at this point, Colombia shows a better oil production for its citizens without Mexico having a very low one.

Table-4. Database applying natural logarithm.

COUNTRY	P.OIL	P.GAS	P.ELE	INF	HDI	GDP	GDP per capita
COLOMBIA	6,83521684	2,39425228	24,8474928	17,6773072	-3,81671283	-0,32989392	12,8207528
USA	8,96715481	6,47895501	29,0417642	19,5705921	-4,19970508	-0,065072	16,6032711
CANADA	8,16667071	5,07816932	27,1512095	17,3615211	-4,60517019	-0,09321238	14,4151407
BRAZIL	7,69298471	2,81540872	26,9974627	19,110033	-2,78062089	-0,31471074	14,6282653
RUSSIA	9,23798764	6,40854527	27,6864558	18,7762774	-2,68824757	-0,23825719	14,5234537
IRAQ	7,93669947	0,61518564	24,5818881	17,3330994	-3,91202301	-0,52763274	11,9141817
CHINA	8,31621712	4,63015544	29,2358484	21,0260341	-3,64965874	-0,35810454	15,9387776
MEXICO	7,98540947	3,96024158	26,4136253	18,5703652	-3,21887582	-0,25489225	13,9841177
VENEZUELA	7,90849745	3,45946629	25,5721662	17,2130578	-0,57625343	-0,2903523	12,8542852
IRAN	8,37126528	5,02256386	26,202654	17,2130578	-0,8603831	-0,29840604	12,743805
ARGENTINA	6,4083146	3,68361562	25,5049072	17,207796	-1,5702172	-0,20948722	12,2292079

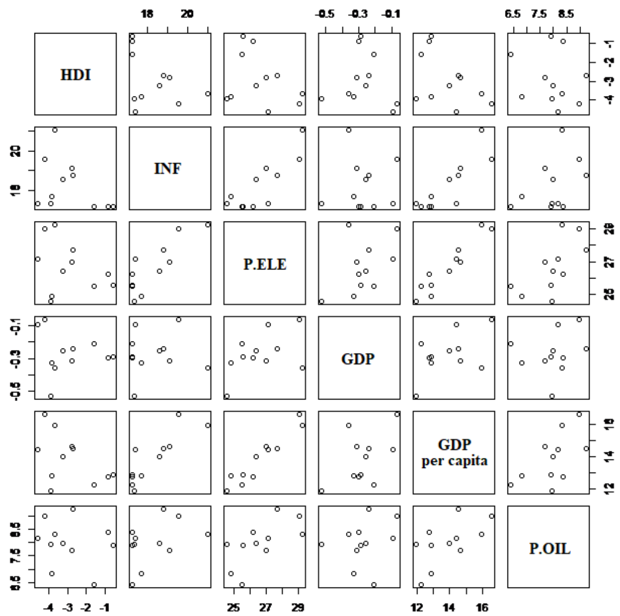
Source: self-made



Source: Prepared by software R studio.

Figure-4. Chernoff faces based on Table 4 natural algorithm.

The dispersion matrix allows visualizing the relationships between the variables analyzed in the economic, social and energy growth of the countries: Colombia, Venezuela, Mexico, Brazil, Argentina, United States, Canada, Russia, Iraq, Iran and China, see Figure-5. This graph shows that there is a relationship between inflation and electricity production, between electricity production and GDP precipitates, and between GDP precipitates and oil production. The graph shows that there is not a good relationship between the human development index with the economic variables of inflation, total GDP and per capita, and the energy variables; production of oil, gas, and electricity.



Source: Prepared by software R studio.

Figure-5. Scatter plot based on table IV natural logarithm.

CONCLUSIONS

Global energy development is of great importance as it has a direct impact on the social and economic development of countries. This situation is clear from the World Summit on Sustainable Development (CDMS, 2002) held in Johannesburg, South Africa. At the WSSD, the international community reconfirmed that access to energy is important to the Millennium Development Goal of halving the proportion of people living in poverty by 2015. The summit also called for changes in unsustainable patterns of energy production and consumption. The agreement reached at the World Summit, the Johannesburg Plan of Implementation (PIJ), places energy on the sustainable development agenda as of vital importance both for the eradication of poverty and the change of consumption and production patterns.

With the development of this work, it has been possible to disprove the hypothesis of the similarity that Colombia has in terms of economic, social and energy development growth with the countries of South America: Brazil and Argentina. Since the Colombian country does not have similar characteristics to the South American countries of Brazil and Argentina, since the Brazilian country in its energy development has a higher capacity, it has one of the most attractive emerging economies for foreign investment, exports, it has large companies from different economic sectors and in the social aspect have a significant HDI, which represents a well-being for their citizens. In the case of Argentina, it falls short in terms of its energy development with respect to Colombia, in relation to its economy its inflation is high, but its GDP per capita is a little higher than the Colombian and in the social aspect Argentina it has a better HDI than Colombia, without the latter having a low one.

The Chernoff graphs show that Colombia has economic and social growth and energy development with Mexico if the population is not considered as a characteristic variable of the information and with China the population is taken into account.

According to the Chernoff graph without population, it shows that Colombia has an economic, social and energetic growth similar to Mexico, where the higher the inflation, the higher the hair height and for this case the graph reflects a low inflation for both countries; the higher the GDP per capita, the greater the width of the hair would be, which in this case is high for both; the higher the oil production, the greater the height of the eyes, in this case Colombia reflects a higher oil production than Mexico, without having this a very low one and finally, the higher the HDI, the greater the width of the eyes at this point, Mexico shows a better HDI for its citizens without Colombia having a very low one.

For the socio-economic-energy projection of Colombia, it is proposed that it should aim to have a similarity with Canada, since this is a power in different fields such as social and economic development, providing the nation with stability in all its spheres , which is positively projected worldwide, in the case of its energy development it would be very beneficial, since in this way the relationship with its social indicators would have a great performance and would not be so affected by the social factor, but rather This would positively influence the economic development of the country.

In general, the most developed country is the US and facial features must have that future trend to achieve a balance in the variables analyzed.

REFERENCES

Amir B. Ferreira Neto, F. S. 2014. Comparing energy use structures: An input-output decomposition analysis of large economies. Energy Economics. pp. 102-113.

Balke NS B. S. 1999. Oil price shocks and the US economy: where does the asymmetry originate? Working paper. Dallas: Federal Reserve. Dallas: Bank of Dallas.

Banrep. (s.f.). Banco de la Republica de Colombia.Obtenido de http://www.banrepcultural.org/blaavirtual/ayudadetareas/frecdos/frecdos19.htm

Berndt E. 1990. Energy use, technical progress and productivity growth: a survey of economic issues. J. Product. 67-83.

C.-Y. Ho, K. S. 2007. A dynamic equilibrium of electricity consumption and GDP in Hong Kong: an empirical investigation. Energy Policy. 2507-2513.

CDMS. 2002. Report of the World Summit on Sustainable Development. Johannesburg, South Africa: United Nations publication.

Cepal. 2002. Globalización y desarrollo. Brasilia.

Chambers J. C. 1983. Graphical methods for data analysis. New York: New York: Champman & Hall.

Chernoff. 1973. The use of faces to represent points in k-dimensional space graphically. Journal of the American statistical Association. 361- 368.

Cienfuegos J. 2013. Diferencia de precios entre las distintas marcas de medicamentos y los medicamentos genéricos comentario de estudio hecho por ANADEUS. Rev. Chilena de Salus Pública. 17(2). doi:10.5354/0717-3652.2013.27091.

Cohen C. 2005. Padrões de Consumo, energia e meioambiente. Parr Texto DISCUSSÃO n. 185. IE / UFF, Niteró.

Contreras, J. A. 2014. Estrategia de cobertura con productos derivados para el mercado energético colombiano. Estudios Gerenciales. 55-64.

D.F. Banes, W. F. 1996. Rural energy in developing countries: a challenge for economic development. Annu. Rev. Energy Environ. 21, 497-530.

DANE. (s.f.). Preguntas frecuentes. Recuperadoel Abril de 2014, de https://www.dane.gov.co/files/faqs/faq_pib.pdf

ER Larsen, I. D. 2004. Lecciones de la desregulaciónen Colombia: Éxitos, fracasos y El Camino a Seguir. Política Energética.

Esso. 2010. Threshold cointegration and causality relationship between energy use and growth in seven African countries. Energy Economy. 1383-1391.

International Monetary Fund (IMF). 2007. World Economic Outlook. Spillovers and cycles in the global economy. International Monetary Fund.

Fouquet R. 2009. International Handbook on the Economics of Energy, Edward Elgar, Northampton.

Fouquet R. 2010. The sustainability of 'sustainable' energy use historical evidence on the relationship between economic growth and renewable energy. BC3 Working Paper.

Fukumori M. 1990. An Application of Statistical Graphs to Cluster Analysis. Journal of Chugoku JuniQr College 4(9): 243-252.

Fukumori M. 1995. Evaluation of multivariate graphs. Journal of Chugoku JuniQr College.

Garneau C. P. (s.f.). The use of humanoid glyphs in graphs for representing human variability in the spatial design of products.

Griffin K. 2001. Desarrollo humano: origen, evolución e impacto. P. Ibarra y K. Unceta (coords.), Ensayossobreeldesarrollohumano. Barcelona, Icaria.

Hamilton J. 1996. This is what happened to the oil price-macroeconomy relationship. J Monetary Economy. 215-220.

Honty G. V. 2005. Energía 2025. Escenariosenergéticos para el Mercosur. Recuperadoel 21 de Abril de 2014, de Fundación M'Biguá.

Instituto Brasileiro de Geografía e Estatística. 2013. Instituto Brasileiro de Geografía e Estatística. Recuperadoel Marzo de 2014, de http://www.ibge.gov.br/paisesat/main.php

International Energy Agency (IEA). 2008. Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis.

J. Darmstadter J. D. 1977. How Industrial Societies Use Energy: a Comparative Analysis. Johns Hopkins University Press, Baltimore.

J. Moral-Carcedoa, J. V.-O. 2005. Modelling the non-linear response of Spanish electricity demand to temperature variations. Energy Economic. 27, 477-494.

J. Zhao J. F. 2007. Empirical research on the inherent relationship between economy growth and energy consumption in China. Economic Research. 31-42.

J. H. Brown W. B.-S. 2011. Energetic limits to economic growth. Bioscience. 61, 19-26.

Jorgenson D. 1984. The role of energy in productivity growth. Am. Econ. Rev. 74, 26-30.

K. A. Mork O. O. 1994. Macroeconomic responses to oil price increases and decreases in seven OECD countries. Energy Journal. 19-35.

Kenneth P. Green, A. a. 27 de May de 2013. Canada as an Emerging Energy Superproducer. Fraser Institute. Recuperadoel 12 de Marzo de 2014, de <http://www.fraserinstitute.org/uploadedFiles/fraser-ca/Content/research-news/research/publications/canada-as-an-emerging-energy-superproducer.pdf

M. A. Toman B. J. 2003. Energy and economic development: an assessment of the state of knowledge. Energy J. 93-112.

Matos L. 2010. The Many Faces of Multivariate Data: Chernoff Faces. Center for Computer Graphics.

Mejía Soto J. & Solarte G. 2013. Sparse Matrix description and application .Scientia et Technica. 18(1).

Mensah. 2013. Time Varying Dynamics of Aggregate Energy Demand in Ghana. Working. Department of Economics, Swedish University of Agricultural Sciences.

N. Apergis J. P. 2010. The emissions, energy consumption and growth nexus: evidence from the commonwealth of independent states. Energy Policy. 650-655.

Oksanen J. 2011. Multivariate analysis of ecological communities in R: vegan tutorial. R package version. 2.0-1.

Pao H. 2005. Comparing linear and nonlinear forecasts for Taiwan's electricity consumption. Energy.

Peet J. 2004. Economic systems and energy, conceptual overview. Encyclopedia of Energy, Elservier, Oxford.

Pitt L. M. 2011. Using Chernoff faces to portray social media wine brand images. En 6th AWBR International Conference, Bordeaux, France.

Restrepo C. (s.f.). Universidad Nacional de Colombia-Sede Manizales. Recuperadoel Marzo de 2014, de http://www.virtual.unal.edu.co/cursos/sedes/manizales/4010043/lecciones/9nocimacroec3.htm

Ríos X. 2004. Rusia y China enelescenario global. Anuario CIP.

Rosenberg N. 1998. The role of electricity in industrial development. Energy J. 19, 7-24.

Schurr S. 1984. Energy use, technological change and productivity efficiency: an economic historical interpretation. Annu. Rev. Energy. 9, 409-425.

Vera I. 2007. Energy indicators for sustainable development. Energy. 875-882.