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*New Research Questions
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**ECONOMIC COMPLEXITY AND THE SUSTAINABLE DEVELOPMENT GOALS: AN
ANALYSIS OF EFFICIENCY THROUGH THE DEA METHOD**

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An efficiency analysis of economic complexity and Human Development in 2013

E – SDGs and Society

Aim of submission

The aim of this paper is to create an indicator that compares the efficiency of countries in converting economic complexity into human development through the Data Envelopment Analysis (DEA) method and econometric validation. The DEA will not only enable comparisons of efficiency across countries, but will also enable the creation of a global indicator and social efficiency rankings.

Theoretical background

Studies have analyzed the relationship between economic development and quality of life. Indexes that analyze social issues were developed in response to the interpretation that the growth of Gross Domestic Product (GDP) is sufficient for the well-being of the population. The growth cannot be the goal of a nation, but rather a strategy to achieve greater benefits for the population and promote human development.

Many economic sectors have been created since the Industrial Revolution, changing the goods produced and the social actors during the process of economic development (Saviotti and Pyka, 2013). Recent studies have reviewed this issue, through the analysis of the export agenda, to predict the pattern of diversification, economic growth and income (Hausmann et al., 2014; Hartmann, 2014). Economic complexity has argued that countries with high per capita income are characterized by the diversification of the export agenda and the extent to which technology-intensive products can be exported. Developed economies show higher GDP growth due to their production of more complex goods, which are interconnected by a broader set of products and industries. Economic diversification leads the country to economic growth and long-term income growth.

Hausmann et al. (2014) define complexity as the productive structure of a nation. The ability to produce machinery, medical equipment and other high-tech is considered more complex than the ability to export commodities. Nations with low diversification are able to export less products with less technological intensity. The importance of exporting high-tech products occurs because of the competitive advantage in the global economy. Countries capable of producing technological goods with diversified exports make the domestic market more dynamic, which requires more sophisticated and rare capacities.

One way to verify the degree of complexity of a country is by Economic Complexity Index (ECI), calculated through data from the United Nations. The ECI shows the characteristics of production through exports. Higher ECI means more diversified export agenda and complex economy. R&D spending is another important variable because diversification and export of high technology products requires innovation. Companies carry out research and development activities, which generate better quality goods, to create new routines and make production more efficient. These research activities provide knowledge necessary for the development of innovations. New sectors and the improvement of the products compensate for the decrease in the capacity of the established sectors by generating new jobs of skilled labors (Saviotti e Pyka, 2013).

The structural change caused by innovation is the main way of creating new sectors, which are fundamental for sustain economic development. This requires technical and social changes, as well as the development of new skills useful to the company and society. An economy focused on the export of technological products and R&D grows at and develop socially.

The urban centers present in the complex economies tend to offer better infrastructure and require more capacities of the agents involved. Hartmann (2014) argued that the region where people live can influence their abilities. The jobs generated in urban centers are generally technologically intensive, requiring greater technical training and a network of knowledge shared by several individuals. This demonstrates the influence of economic complexity on human development. While growth helps fight poverty and other social problems, the complexity of the economy corroborates that people better develop their capacities (education, health, access to technology, and infrastructure) by contributing to social progress. A complex country creates new sectors of activity and generates better quality jobs, this makes a country more robust to face economic crises.

Economic Complexity and Human Development

For production, factors such as capital, land and labor are needed. Countries also need to have adequate infrastructure, property rights, regulations, labor skills and skilled labor. However, Hausmann et al. (2014) argue that knowledge is also a relevant production factor. Economic Complexity is related to the types of products developed due to the multiplicity of available knowledge. For an economy to remain complex, individuals from diverse areas (finance, marketing, technology, human resources, operations, law, among others) must interact and combine their knowledge.

Hartmann (2014) finds a strong correlation between complexity, income inequality, education and GDP growth. More complex countries show greater growth of GDP and more egalitarian income distribution. One example is the increase in productivity in South Korea, which is linked to the strong improvement in the accumulation of human capital. The average number of years of schooling increased from 4.1 in 1960 to 12.0 in 2010. In China, there are still significant gaps in human capital indicating that the Chinese government could stimulate economic growth through educational investment.

In a comparison about income inequality and economic complexity, Latin America, which has enjoyed soaring commodity prices over the last decade, has improved social indicators but it is not enough to promote structural change. This reflected the lack of opportunities in better quality jobs. On the other hand, Asian countries have invested in human capital and technological innovation making their economies more complex and improving the quality of life of the population.

Structural change is important as new technological sectors raise average wages and the demand for skilled labor, which requires higher educational levels (Antonelli, 2016). Labor-specialized education increases per capita income and consumer purchasing power, as well as improving the quality of goods produced by skilled workers. This virtuous cycle plays a fundamental role in transforming societies with an abundance of low-skilled workers.

In Japan, agricultural mechanization freed the labor force for the industrial sector raising wages and generating urbanization. This process lasted about 15 years and occurred due to productivity growth in all economic sectors. In non-agricultural activities, productivity increased due to the adoption, imitation, and assimilation of advanced knowledge flows, which depended on the level of human capital.

In contrast, South Korean development policy is based on exports, trading open the door to the import of cheaper intermediate goods and access to advanced technologies which contributed to the rapid growth of the productivity of the industry. The export policy for industrialization encouraged the performance of exporters by generating comparative advantage of Korean companies in international trade. These labor-intensive industries have become capital-intensive in electronics, machinery, automobiles, ships, and information and communications technology. Consequently, Korean per capita income has reached the level of developed countries.

In Latin America, the development model is criticized because the modern and productive sector compete with the primary production sector. The availability of land for cultivation absorbs workers and migrants from rural areas, displacing skilled labor from other sectors of the economy. The region is susceptible to the "Dutch Disease" effect of a sector of expanding primary products. As the price of commodities increases, production and employment grow, specializing the region in the export of primary products. Data from the World Bank shows that 55.3% of merchandise exports consist of primary products, corresponding to 63.5% of total exports. Only 20.8% of the workforce is in industry and the poverty rate is 41.2%. The results show inadequate access to the transportation system, infrastructure and the international market.

For example, in Brazil, the government still needs to improve the strategy for industrial development. One successful example is the adoption of biotechnology for soy production, which has reduced the intensity of the workforce in agriculture and expanded employment in industry. Another example is mechanization in the cultivation of sugarcane, which practically wiped out migratory flows in the poorest regions and generated employment opportunities for skilled labor in the country or the shift from a fossil-based to a bio-based economy (bioeconomy) which requires more efficient utilization of the biomass generated from agricultural production. On the other hand, there is still technological adoption that is detrimental to local industry, such as the development of a technology that intensified corn planted area, which increased agricultural labor and contracted industrial employment.

Methodology

An efficient system is one that performs tasks using the minimum possible resources to obtain the maximum yield. An autonomous system can be called a Decision Making Unit (DMU). The DMU transforms a set of inputs into a set of outputs. The method used to determine the system's efficiency is called Data Envelopment Analysis (DEA).

DEA is a non-parametric mathematical method based on linear programming and developed by Charnes, Cooper and Rhodes in 1978. The approach aims through the empirical construction of a linear boundary in pairs to measure the productive efficiency of a set of DMUs.

The efficient frontier expresses the maximum number of outputs that can be produced per unit of inputs, representing the production limit determined by the technology. It acts as a border separating the efficient DMUs, which are at the border boundaries, from the inefficient ones that lie below them, so that the distance from a DMU to the border is an indication of their level of efficiency. Effective DMUs represent a "best practice frontier" which serve as an analysis of the least efficient ones.

There are different models that can be used to implement DEA. The Constant Return to Scale (CRS) hypothesis considers that the outputs vary proportionally to the inputs in all regions of the border. However, this model does not consider the scale gains of a system. The hypothesis of the Variable Return to Scale (BCC or VRS) model considers that the variation of the outputs is not necessarily equiproportional to the inputs, being that in the border there will be three regions: increasing, in which the outputs grow proportionally more than the inputs; proportionality, when the model is operating on great scale; and decreasing, where outputs grow proportionately less than inputs.

Radial models focus on minimizing inputs or maximizing outputs separately, since: a) input-oriented models seek to determine, given the current level of outputs, how much inputs could be reduced; And b) output-oriented models seek to determine, given the current level of inputs, how much output could be increased. The non-radial orientation aims to simultaneously reduce the inputs and increase the outputs.

Tone (2001) developed a non-radial model called Slack-Based Measure (SBM). This model deals with gap variables, that is, the excesses of inputs and the scarcity of outputs. The SBM projects the observations to the point farthest from the efficiency frontier to minimize the objective function in relation to the maximum clearance amounts. SBM is an additive DEA model, invariable in relation to the units of measure used for inputs and outputs. This means that this model reaches the same efficiency value, regardless of the units of measure adopted for each variable.

For this article, we selected 49 countries (DMUs) with data from the World Bank in 2013. The selected variables are corresponding the economic complexity (export of high technology products and R&D expenditures) and human development (education, longevity, basic sanitation and employment).

Econometric analysis has shown that all social variables (outputs), except the average years of study and the employment rate have statistically significant correlation. All variables presented an expected signal. R&D expenditures showed higher correlation with life expectancy (16.71%), followed by the sanitation rate (12.12%). In relation to the export variable of high technology products, it is verified that all social variables presented a positive correlation and were statistically significant. Life expectancy (23.94%) was the social variable that presented the highest correlation, followed by the employment rate (22.11%), sanitation rate (15.87%) and average years of study (12.41%).

Besides, were estimated eight econometric models, in order to analyze which variables best explain the variability of each social variable analyzed. In addition to verifying the statistical significance of the parameters and the adjusted R^2 , a comparative analysis of the Akaike (AIC) and Bayesian (BIC) information criteria was used to select the best model. In summary, the econometric analysis showed that the inputs selected for this study are correlated and have statistical significance with the social variables (results), confirming the theoretical assumptions.

Results and implications

This study considered as traditional models those with Constant Scale Returns (CCR) and Scale Variable Returns (BCC). As expected, the CCR model obtained fewer efficient DMUs (3 DMUs) than the BCC model (25 DMUs). This is because, when considering the scale of each nation, countries like Belgium, Canada, China, Germany, Japan, South Korea, Spain, England, USA and others have become efficient.

The BCC estimates showed to be better adjusted to the above-mentioned theoretical discussions, besides presenting better adjustment, because the mean (0.982) and the standard deviation (0.0255) of the efficiency of the countries analyzed by the BCC model were better than those found for the CCR model (0.4052 and 0.3124, respectively).

In relation to the models based on slack, models with constant returns to scale (CRS) and variable returns to scale (VRS) were estimated. The SBM-CRS model presented the same efficient countries as the traditional CCR model. In the model SBM-VRS was found a smaller number (13 DMUs) of efficient countries in relation to the BCC model. The twelve countries that left the efficiency frontier between the traditional model and the slack model were: Austria; Belgium; China; Denmark; Greece; Israel; Italy; South Korea; Portugal; Spain; Switzerland; and, USA.

Table 1 - Estimates of the efficiency of traditional models and SBM

Countries	Traditional Models			Slack Based Models		
	CRS	VRS	Scale Ef.	SBM-CRS	SBM-VRS	Scale Ef.
Argentina	0.1261	0.9580	0.1316	0.1139	0.8977	0.1269
Armenia	0.0576	0.9148	0.0630	0.0556	0.9023	0.0616
Austria	0.4354	1.0000	0.4354	0.4066	0.9996	0.4068
Belarus	0.0704	0.9440	0.0746	0.0659	0.9017	0.0731
Belgium	0.4502	1.0000	0.4502	0.4265	0.9996	0.4267
Brazil	0.1154	0.9894	0.1166	0.0814	0.8346	0.0975
Bulgaria	0.9352	0.9701	0.9640	0.8774	0.8774	1.0000
Canada	0.4496	1.0000	0.4496	0.4216	1.0000	0.4216
Chile	0.1453	0.9900	0.1468	0.1316	0.9090	0.1448
China	0.0633	1.0000	0.0633	0.0424	0.9999	0.0424
Colombia	0.0752	0.9166	0.0820	0.0556	0.7786	0.0714
Costa Rica	0.0974	0.9606	0.1014	0.0834	0.8503	0.0981
Croatia	0.2237	0.9772	0.2289	0.2035	0.8865	0.2296
Czech Republic	0.1736	0.9910	0.1752	0.1667	0.9478	0.1759
Denmark	0.5336	1.0000	0.5336	0.5103	0.9999	0.5104
El Salvador	0.9450	0.9450	1.0000	0.7879	0.7879	1.0000
Estonia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Finland	0.4229	0.9841	0.4297	0.4041	0.9423	0.4288
France	0.3977	0.9973	0.3988	0.3819	0.9388	0.4068
Germany	0.4136	1.0000	0.4136	0.3842	1.0000	0.3842
Greece	0.4179	1.0000	0.4179	0.3624	0.9996	0.3625
Hungary	0.1297	0.9800	0.1323	0.1216	0.8809	0.1380
Ireland	0.4807	1.0000	0.4807	0.4521	1.0000	0.4521
Israel	0.3660	1.0000	0.3660	0.3496	0.9999	0.3496
Italy	0.3588	1.0000	0.3588	0.3210	0.9997	0.3211
Japan	0.3468	1.0000	0.3468	0.3369	1.0000	0.3369
Korea, Rep.	0.2294	1.0000	0.2294	0.2170	0.9850	0.2203
Lithuania	0.9920	0.9920	1.0000	0.9605	0.9605	1.0000
Luxembourg	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mexico	0.1052	0.9293	0.1132	0.0861	0.8277	0.1040
Netherlands	0.4495	1.0000	0.4495	0.4169	1.0000	0.4169
Norway	0.9428	1.0000	0.9428	0.8617	1.0000	0.8617
Panama	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Poland	0.1216	0.9697	0.1254	0.1167	0.9281	0.1257
Portugal	0.2733	1.0000	0.2733	0.2377	0.9996	0.2378
Romania	0.2299	0.9257	0.2484	0.2185	0.8837	0.2473
Russian Federation	0.1357	0.9594	0.1414	0.1113	0.8604	0.1294
Serbia	0.0605	0.9650	0.0627	0.0539	0.8250	0.0653
Singapore	0.5011	1.0000	0.5011	0.4218	1.0000	0.4218
Slovak Republic	0.9871	1.0000	0.9871	0.9400	1.0000	0.9400
Slovenia	0.6532	1.0000	0.6532	0.6337	1.0000	0.6337
Spain	0.2518	1.0000	0.2518	0.2224	0.9999	0.2224
Sweden	0.5171	1.0000	0.5171	0.4921	0.9996	0.4923
Tunisia	0.9427	0.9594	0.9826	0.7519	0.7519	1.0000
Turkey	0.1202	0.9410	0.1277	0.1024	0.7871	0.1301
Ukraine	0.0545	0.9620	0.0567	0.0517	0.9228	0.0560
United Kingdom	0.3910	1.0000	0.3910	0.3646	1.0000	0.3646
United States	0.4846	1.0000	0.4846	0.4556	0.9999	0.4556
Uruguay	0.1804	0.9978	0.1808	0.1473	0.9137	0.1612
Average	0.4052	0.9820	0.4098	0.3757	0.9383	0.3950
St Dev	0.3124	0.0255	0.3126	0.2977	0.0747	0.3117

This is an important result because it demonstrates that traditional models can make economically developed countries be efficient, that in reality are inefficient in transforming economic complexity in human development because they have excess inputs or lack of outputs. As a consequence of this BCC limitation, the SBM-VRS model showed a lower average (0.9383) and higher standard deviation (0.0747) of efficiency among the analyzed countries.

In summary, the estimates found demonstrated that although the BCC model presents good estimates for the countries' efficiency, the SBM-RSV model allowed only to be observed the really efficient countries, considering the slacks that may exist when converting complexity in quality of life.

This article contributed to consider economic complexity as a new variable to obtain the countries' efficiency in generating human development. The initial hypothesis of this work was confirmed, in view of more complex countries were more efficient in generating human development.

As study limitation was not used variables that measure country inequality and the democratic environment. It is concluded that the more complex countries, especially Austria, China, South Korea, Israel, Japan, Singapore and England, have remained more efficient than the other countries analyzed. This result reinforces the importance of policies focused on economic development through an industrial policy that prioritizes the diversification of the export agenda for technologically intensive products and the importance of social policies for generating quality of life in countries with low economic complexity. It is argued, therefore, that formulators of industrial and social policies develop them in a complementary and strategic way, in order to generate social benefits to the population.

Key words: Economic Complexity; Human Development; Sustainable Development Goals; Data Envelopment Analysis (DEA).

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