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Transformation of wealth produced into quality of life: analysis of the social efficiency of nation-states with the DEA's triple index approach

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Although an essential condition for the occurrence of human development, economic growth is not always efficiently converted into quality of life by nation-states. Accordingly, the objective of this study is to measure the social efficiency—the ability of a nation-state to convert its produced wealth into quality of life—of a set of 101 countries. To achieve this goal, the Data Envelopment Analysis method was used in its standard, cross-multiplicative and inverted form, by means of a new approach called 'triple index'. The main results indicated that the former Soviet republics and Eastern European countries stood out in terms of social efficiency. The developed countries, notwithstanding their high social indicators, did not excel in efficiency; however, the countries of south of Africa, despite having the worst social conditions, were also the most inefficient.

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Introduction

Economic growth has been increasingly sought by different countries, based on the essential conditions for improving the population's quality of life. According to Aristotle (1996), the wealth generated by economic growth should not be viewed as an end in itself, but only as an instrument for achieving happiness.

According to Lewis (1955), economic growth should be seen as a mechanism that enables expansion, if not happiness, at least for individual freedoms and the possibility for human beings to choose. Thus, from the assumption that development is understood as the process of expanding individual freedom (Sen, 1999), it can be concluded that the main role of economic growth is to assist in promoting human development while generating quality of life.

It should be emphasized that the relationship between economic growth and quality of life is not automatic, nor is it obvious (UNDP, 2000), which can be corroborated by the analysis of Sen (1998), who correlated the variables 'income' (economic indicator) and 'life expectancy' (social indicator), and found that certain countries with lower per capita income have a higher life expectancy than countries with higher per capita income. Thus, it can be argued that it is not economic growth in itself but rather its quality that determines the well-being of the population, and this quality is evaluated by the capacity to reduce extreme poverty, reduce inequalities and promote self-sufficiency (López *et al*, 2008). In short, economic growth is a necessary but not sufficient condition for all to achieve fuller and happier life conditions (Ranis *et al*, 2000; Kliksberg, 2001).

The theme of this work is the relationship between the economic growth and human development of a nation-state; but as this relationship is complex and multidimensional, it is difficult to directly analyse it. Thus, it is highly recommended to mediate this analysis through the concept of efficiency, which measures the ability of systems to convert, in suitable proportions, a set of inputs into a set of outputs. Therefore, in this study, which was based on Despotis' (2005a, b) 'paradigm of transformation' proposal, the countries were analysed as if they were productive systems, whose purpose is to transform the wealth produced (input) into quality of life (output).

The objective of this research is *to determine, with a new Data Envelopment Analysis* (DEA) *approach called 'triple index', the 'social efficiency' of a set of nation-states*, which is an indicator of a country's performance in converting wealth produced into quality of life.

It should be mentioned that a considerable number of studies can be found in the literature that used DEA to evaluate the efficiency of the transformation of productive resources into quality of life as the human development itself of countries, cities or regions, some of which took into account only the dimensions of the Human Development Index, HDI (Mahlberg and Obersteiner, 2001; Despotis, 2005a, b; Romero and Fortes, 2007; Despotis *et al*, 2009; Romero *et al*, 2009; Bougnol *et al*, 2010; Zhou *et al*, 2010; Tofallis, 2013), while others took into

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account alternative social dimensions (Hashimoto and Ishikawa, 1993; Hashimoto and Kodama, 1997; Martic and Savic, 2001; Ramanathan, 2006; Chabaan, 2009; Fidalgo *et al*, 2009; Hashimoto *et al*, 2009; Malul *et al*, 2009; Somarriba and Pena, 2009; Morais and Camanho, 2011; Poveta, 2011; González *et al*, 2011a, b; Blancard and Hoarau, 2013). A much smaller number of papers have examined what was termed, in this paper, 'social efficiency' (Raab *et al*, 2000; Despotis, 2005a, b; Romero and Fortes, 2007; Romero *et al*, 2009).

Accordingly, the main contributions of this paper, compared with other papers published on this theme, are (a) the realization of a global analysis of social efficiency using a larger scope of indicators than that contained in the HDI; (b) the use of weight restrictions and a new approach for discriminating Decision Making Units (DMUs), called 'triple index'; (c) the use of a temporal lag between the inputs and outputs; and (d) the construction, through a literature review, of a theoretical framework that allowed the analysation and discussion of the social efficiency of nation-states.

This paper is structured as follows. In the next section we discuss the important papers committed to the theme of social efficiency. Next, the theoretical framework that supports the analysis of the social efficiency of nation-states is presented. The subsequent section presents the main concepts related to DEA. The section that follows presents and discusses the formulations for the new approach called 'triple index'. The section 'Research variables' describes and substantiates the variables that were selected to quantify the human development of a country. The following section details the method used in this study. The section after that includes a discussion of the preliminary analysis of the data. The penultimate section depicts the social efficiency results and the power of discrimination of the 'triple index'. Finally, the last section presents the conclusions and suggestions for future works.

State of the art

As the pioneer who explored the issue of 'social efficiency', Despotis (2005a) proposed an approach called 'paradigm of transformation' of HDI, which uses as input the GDP per capita index, while the outputs are the education and life expectancy indices. This approach was applied in the work cited, using the DEA method, with the 2000 data from 174 countries. The countries were divided into three groups using the GDP per capita, and performing two types of analyses: (1) comprehensive, with all countries; and (2) with each group separately. Table 1 shows the countries that were socially efficient, both within their groups and in the overall analysis.

Despotis (2005b) adopted the same HDI transformation paradigm to evaluate the social efficiency of Asian and Pacific countries in 2000, and for this, two different analyses that only varied the input were performed: (A1) the real GDP per capita index and (A2) the GDP per capita adjusted by the Purchasing Power Parity (PPP) index. Both analyses achieved the same efficient set of countries, composed of Hong Kong, Fiji, South Korea, Mongolia, Myanmar, Nepal, Vietnam, Philippines, the Solomon Islands and Sri Lanka. Romero *et al* (2009) and Romero and Fortes (2007) used the HDI paradigm of transformation to calculate, respectively, the social efficiency of historic cities and the largest cities in the state of Minas Gerais, Brazil.

Table 1 Socially efficient countries in 2000

GPD per capita	*Efficient countries*
High	Canada, Sweden, Japan, the United Kingdom, New Zealand, Spain and Greece
Average	Estonia, Cuba, Georgia, Ukraine and Jamaica
Low	Azerbaijan, Tajikistan, Armenia, the Solomon Islands, Yemen, Tanzania, Malawi and Sierra Leone

Source: Constructed from Despotis (2005a).

Morais and Camanho (2011), extending the simple use of the HDI dimensions, assessed the social efficiency of 284 European cities. For this purpose, the GDP per capita at PPP was used as the only input, and 29 indicators of quality of life were used as outputs, related to the following dimensions: (1) demographics, (2) social, (3) economic, (4) civic, (5) educational, (6) environmental, (7) transportation, (8) informational and (9) cultural. The European countries with the most efficient cities were Germany, Bulgaria, Romania, Estonia and Slovakia.

Lastly, Raab *et al* (2000) analysed the efficiency of underdeveloped countries by converting GDP per capita into children's well-being; this specificity meant that, in addition to the GDP per capita at PPP, other inputs had to be added to the analysis, such as (a) women's literacy rate; (b) average age of women at first marriage; and (c) number of doctors per capita. The outputs used were (1) children's survival rate; (2) number of well-nourished children; and (3) number of literate children. As a result, it was found that the most efficient underdeveloped countries, in terms of children's welfare, were Jamaica, Costa Rica, Chile and Uruguay.

Table 2 shows the systematized papers presented in this section. It can be stated, based on Table 2, that the 'social efficiency' approach was not very systematic in the literature, addressed only in few and recent works. It is also worth commenting that different techniques or more sophisticated DEA models were not used much in this area, such as those associated with weight restrictions or tiebreaker methods, and in all the papers found, variable returns to scale (VRS) models were used.

Wealth, quality of life and social efficiency

The relationship between the income per capita and quality of life variables can be considered as cyclic, where the increase of one will generate, as a consequence, the increase of the other. According to Cracolici *et al* (2009) and Ranis *et al* (2000),

Table 2 Summary of the papers that used the social efficiency approach

Author	*University*	*DEA model*	*Inputs*	*Outputs*
Despotis (2005a)	World (174 countries)	VRS	GDP per capita index of IDH	Longevity and education indexes of IDH
Despotis (2005b)	Asia and Pacific (27 countries)	VRS	*2 analysis*: Indexes of (A1) GDP per capita in current dollars and (A2) GDP per capita at PPP	Longevity and education indexes of IDH
Morais and Camanho (2011)	European cities (206 cities)	VRS with weight restrictions	GDP per capita at PPP	29 indicators of quality of life
Raab *et al* (2000)	Underdeveloped countries (38 countries)	Variant Additive Model	GDP per capita at PPP, women's literacy rate, average age of women at first marriage and number of doctors per capita	Fours indicators of child welfare
Romero and Fortes (2007)	Brazilian cities (64 cities)	VRS	GDP per capita index of IDH	Longevity and education indexes of IDH
Romero *et al* (2009)	Brazilian cities (23 cities)	VRS	GDP per capita index of IDH	Longevity and education indexes of IDH

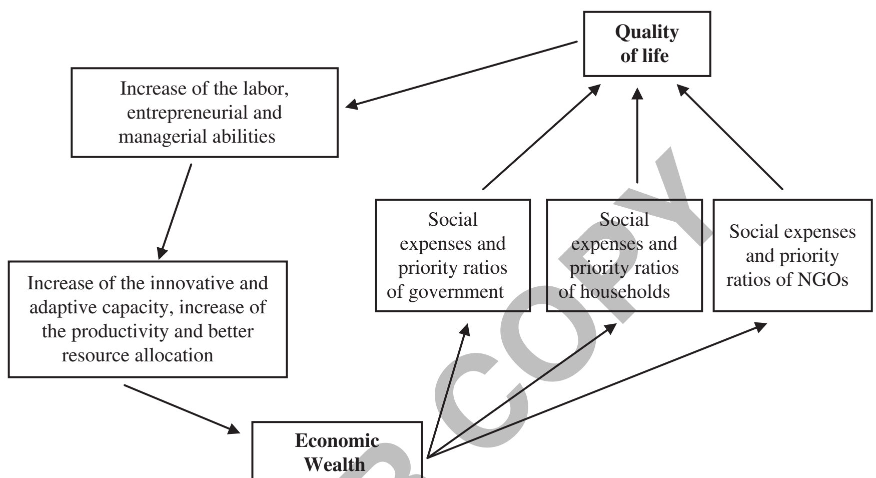

Figure 1 The cyclic relationship between economic wealth and quality of life.
Source: Suri *et al* (2011).

increase in GDP per capita is a fundamental prerequisite to improve the quality of life of the population, since it can provide (a) better-quality health services; (b) greater access to education, safety, leisure and better working conditions; and (c) a more sustainable environment. At the same time, the additional quality of life generated by the production of wealth results in better health and education conditions for the Economically Active Population (EPA), which is a crucial basis for the occurrence of increased productivity, technological progress and GDP per capita of a country (Ranis *et al*, 2000; Cracolici *et al*, 2009). This dual relationship between economic wealth and quality of life was closely examined and systematized by Suri *et al* (2011), as shown in Figure 1.

Nevertheless, it is important to make clear that the ends cannot be confused with the means, and hence the increase in quality of life should be viewed as an end in itself and not merely as the means to attain income per capita increase (Sen, 1999). Therefore, in this study, unlike in the econometric analysis performed by Suri *et al* (2011), the transformation of quality of life efficiency into economic growth will not be evaluated, because growth cannot be considered a final goal, as it is only an instrument.

Ranis *et al* (2000) classify countries into four groups: (a) 'virtuous cycle', which has strong economic growth and strong human development, mutually reinforcing one another; (b) 'vicious cycle', which has weak economic growth and poor human development, which cancel each other out; (c) 'shifted to growth', which has high economic growth, but low human development; and (d) 'shifted to human development', which has low economic growth but high human development. It can be highlighted that the countries in the categories 'shifted to growth' and 'shifted to human development' are in a transient and unstable situation, which tends to become a vicious cycle, in the first case, or a virtuous cycle, as in the second case (Ranis *et al*, 2000). This fact leads to the conclusion that in order to establish a virtuous cycle, priority should be given to human development, and not to economic growth, which will arise automatically as a result of the former (Ranis *et al*, 2000).

Table 3 Categories of countries' economic and social performance

Ranis et al (2000) *classification*	*Cracolici et al* (2009) *classification*	*Economic growth*	*Human development*	*Stability*
Vicious cycles	LL	Low	Low	Stable
Virtuous cycles	HH	High	High	Stable
Shifted to growth	HL	High	Low	Unstable: Tends to Vicious cycles
Shifted to human development	LH	Low	High	Unstable: Tends to Virtuous cycle

Source: Ranis *et al* (2000) and Cracolici *et al* (2009).

Cracolici *et al* (2009) also divide countries into four categories, but incorporate the environmental dimension and use a different nomenclature: (a) High High (HH), equivalent to countries in the virtuous cycle; (b) High Low (HL), equivalent to countries shifted to growth; (c) Low High (LH), equivalent to countries shifted to human development; and (d) Low Low (LL), equivalent to countries in a vicious cycle. Table 3 shows the systematization of these concepts.

Another point to emphasize is that not all economic wealth is fully converted into quality of life, which was empirically verified by Sen (1998). According to Klicksberg (2001), the higher the economic growth, the more resources there will be and the more opportunities for society, which does not guarantee that all will be well used; and also according to this author, economic growth alone could never sustain the process of human development.

Sen (1999), without applying that term, listed some possible factors that influence a country's social efficiency: (a) personal heterogeneities, which are gender-related physical characteristics, ethnicity, age, illness and disability, among others; (b) environmental diversities, which refer to the physical characteristics of the environment, such as weather conditions, presence of infectious diseases and pollution levels; (c) variations in social climate, which is related to public education and health services, and to crime and violence levels; (d) relative differences in perspectives, which refer to changes in consumption needs associated with certain established patterns of behaviour; and (e) poor distribution within the family, which in many cases favours males.

Data Envelopment Analysis

DEA is an Operational Research method that aims, through the empirical construction of a piecewise linear frontier, to measure the productive efficiency of a set of DMUs. DEA, in short, is a mathematical procedure based on linear programming, which is able to find the set of weights that maximizes the efficiency of a DMU, which allows the incorporation of multiple inputs and outputs in one index.

Note that the efficient piecewise linear frontier expresses the maximum number of outputs that can be produced per unit of input, thus representing the production limit determined by the technology of a sector. This frontier separates the efficient DMUs, which are in the frontier limits, from the inefficient ones, which are below them, so that the distance of a DMU to the frontier is an indication of its efficiency level.

There are different models that can be used to implement DEA, and they differ according to the assumptions they adopt, related to (a) the type of returns to scale; (b) the orientation; and (c) the way inputs and outputs are combined.

The type of returns to scale designates the two main DEA models: (a) CRS (Constant Returns to Scale), also called CCR in honour of its developers, Charnes, Cooper and Rhodes (1978); and (b) VRS (Variable Returns to Scale), also called BCC in honour of its developers, Banker, Charnes and Cooper (1984). The hypothesis of CRS considers that outputs vary proportionately to inputs in all the regions of the frontier. The hypothesis of VRS, on the other hand, considers that the variation of the outputs is not necessarily proportional to the inputs; note that a unit in the VRS model can present increase, decrease or CRS. In addition to the CCR and BCC models, the returns to scale determine two other DEA models: (a) NDRS, which works with a hypothesis of Non-Decreasing Returns to Scale; and (b) NIRS, which works with a hypothesis of Non-Increasing Returns to Scale.

The orientation may be the radial type, as found in the CCR and BCC models, or non-radial, found in the additive and multiplicative models. The radial models focus on minimizing the inputs or maximizing the outputs separately, given that (a) the input-oriented models seek to determine, given the current output level, to what degree the inputs could be reduced; and (b) the output-oriented models seek to determine, given the current level of inputs, to what degree the outputs could be increased (Cooper *et al*, 2000). The non-radial orientation simultaneously seeks to reduce the inputs and increase the outputs.

Table 4 shows the basic formulation of the BCC and CCR models in their two orientations. For all models presented in Table 4, the following notation was used:

- h represents the number of DMUs analysed;
- m represents the number of outputs analysed;
- n represents the number of inputs analysed;
- u_i represents the weight of output i for the DMU under analysis;
- v_j represents the weight of input j for the DMU under analysis;
- w represents the scale factor;

Table 4 CCR and BCC models of DEA

Model	*Input oriented*	*Output oriented*
CCR	MAX $\sum_{i=1}^{m} u_i \cdot y_{i0}$ Subject to: $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i . y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leqslant 0, \quad \text{for } k = 1, 2, \ldots, h$	MIN $\sum_{j=1}^{n} v_j \cdot x_{j0}$ Subject to: $\sum_{i=1}^{m} u_i \cdot y_{i0} = 1$ $\sum_{i=1}^{m} u_i . y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leqslant 0, \quad \text{for } k = 1, 2, \ldots, h$
BCC	MAX $\sum_{i=1}^{m} u_i \cdot y_{i0} + w$ Subject to: $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i . y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leqslant 0, \quad \text{for } k = 1, \ldots, h$ w without signal restriction	MIN $\sum_{j=1}^{n} v_j \cdot x_{j0} - w$ Subject to: $\sum_{i=1}^{m} u_i \cdot y_{i0} = 1$ $\sum_{i=1}^{m} u_i . y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leqslant 0, \quad \text{for } k = 1, \ldots, h$ w without signal restriction

x_{j0} represents the amount of input j of the DMU under analysis;
x_{jk} represents the amount of input j of DMU k;
y_{i0} represents the amount of output i of the DMU under analysis; and
y_{ik} represents the amount of output i of DMU k.

Tiebreaker methods of DEA

DEA, due to its system's great freedom to assign weights, often leads to situations in which multiple ties occur between efficient DMUs. According to Angulo-Meza and Lins (2002) and Soares de Mello *et al* (2008), there are two types of tiebreaker method related to DEA: (a) those requiring prior information, which are more subjective; and (b) those that do not require prior information, for instance (1) superefficiency; (2) cross-evaluation; and (3) inverted frontier. Each of these methods takes into account different approaches, and some are considered in this study.

The cross-evaluation proposed by Sexton (1986) and developed by Doyle and Green (1994) involves taking the weights obtained by DEA for all DMUs, and then using them to calculate the efficiency of all units—hence a cross-reference between the weights. With this method, the cross-efficiency of a DMU (E_k^{Cross}) is determined from the average of efficiencies obtained with all the different sets of weights, which causes it to be weighted by the weights that maximize the efficiency of all DMUs, and not just the one being analysed. Expression (1) illustrates how to calculate the efficiency by the cross-evaluation.

$$E_k^{Cross} = \left(\sum_{\forall l} E_{lk} \right) / h \tag{1}$$

where E_k^{Cross} represents the cross-efficiency of a DMU_k; E_{lk} represents the efficiency of the DMU_k calculated with the weights that maximize the efficiency of the DMU_l; and h represents the number of DMUs analysed.

One of the greatest problems of cross-evaluation is the fact that there may be multiple sets of weights that maximize the efficiency of the efficient DMUs. To solve this problem, in order to determine a set of single weights for each DMU, two alternatives were developed: (a) the benevolent model, which determines the set of weights that maximizes the cross-efficiency of the DMUs; and (b) a aggressive model, which determines the weights that minimize this efficiency (Angulo-Meza and Lins, 2002; Alder *et al*, 2002).

The inverted frontier, developed by Leta *et al* (2005), from the proposition by Yamada *et al* (1994), is based on exchanging the inputs with the outputs (building the so-called inverted frontier) and then calculating the 'composite index' (E_k^{Comp}), which is determined by the arithmetic mean normalized between (a) the efficiency calculated with the standard frontier (E_{kk}); and (b) the efficiency calculated with the inverted frontier subtracted from 1 ($1 - E_{kk}^{-1}$). Expression (2) shows how to calculate the 'composite index':

$$E_k^{Comp} = \frac{[(E_{kk} + (1 - E_{kk}^{-1})]/2}{\max_k \{[(E_{kk} + (1 - E_{kk}^{-1})]/2\}} \tag{2}$$

wherein E_k^{Comp} represents the composite index of the DMU_k; E_{kk} represents the efficiency of the DMU_k calculated with the standard frontier; and E_{kk}^{-1} represents the efficiency of the DMU_k calculated with the inverted frontier.

According to the composite index, the most efficient DMU will be that which can show a good performance in its strong points, which is evaluated by the standard efficiency level, and not show a very bad performance in its weak points, which is measured by the efficiency obtained in the inverted frontier subtracted from 1 (Leta *et al*, 2005).

Triple index

In this study we chose to use an indicators set, designated 'triple index'—E_k^{Triple}, which was determined by the weighted geometric mean normalized between (a) the efficiency obtained at the standard frontier—E_{kk}; (b) the 'cross-multiplicative index'—E_k^{MCross}; and (c) the 'inverted index'—E_k^{inv}. Expression (3) illustrates the calculation of the 'triple index'.

$$E_k^{Triple} = \frac{(E_{kk})^{\alpha} \times (E_k^{MCross})^{\beta} \times (E_k^{Inv})^{\gamma}}{\max\limits_k \left\{ (E_{kk})^{\alpha} \times (E_k^{MCross})^{\beta} \times (E_k^{Inv})^{\gamma} \right\}},$$
$$\text{with } (\alpha + \beta + \gamma) = 1 \tag{3}$$

wherein E_k^{inv} represents the 'inverted index' of a DMU_k; E_k^{MCross} represents the 'cross-multiplicative index' of a DMU_k; E_k^{Triple} represents the 'triple index' of a DMU_k; E_{kk} represents the efficiency of the DMU_k calculated with the standard frontier; and α, β and γ represent the weights assigned to each of the components of the 'triple index'.

The reason for integrating these three measurements on a single index was to obtain a performance measure that would aggregate three dimensional analysis: (a) using the most advantageous weights for the DMU; (b) using the most advantageous weights for the other units under analysis; and (c) taking into consideration the distance of the DMU to the frontier of worst practices.

Note that the use of the geometric mean is more appropriate for the 'triple index' because it penalizes large discrepancies between the indicators to be combined, and is therefore widely used to calculate the index numbers, such as those of Fischer, Törnqvist and Malmquist. The main reason for using the geometric mean is that it considered that the three dimensions that were regarded to evaluate the performance of a DMU were not perfect substitutes among each other (Tofallis, 2013). Thus, the poor performance of a DMU in the inverted frontier, for example, could not be fully offset by a good performance in the standard frontier or in the cross-evaluation.

It is important to note that the superefficiency was not aggregated to the triple index because, according to the findings of Banker and Chang (2006), this method is not very suitable for the tiebreak of efficient DMUs, being useful only for determining the outliers.

Inverted index

In the present work, it was decided to not use the 'composite index' proposed by Leta *et al* (2005), but rather a new approach, called 'inverted index'. The 'inverted index' consists of the normalized value of one divided by the efficiency obtained at the inverted frontier, using a reversed orientation ($1/E'^{-1}_{kk}$). Note that using the inverted value of the inverted efficiency seems to be a more appropriate procedure than using it subtracted from 1, since the DEA is formulated based on the ratio between outputs and inputs. It should also be emphasized that it is important to change the orientation when using the inverted frontier (from inputs to outputs and vice versa), so that the calculation of the inverted value of the index obtained keeps the original orientation. Expression (4) illustrates how to calculate the 'inverted index'.

$$E_k^{Inv} = \frac{1/E'^{-1}_{kk}}{\max\limits_k \left\{ 1/E'^{-1}_{kk} \right\}} \tag{4}$$

wherein E_k^{Inv} represents the 'inverted index' of the DMU_k and E'^{-1}_{kk} represents the efficiency of the DMU_k calculated with the inverted frontier, using a reversed orientation.

A major advantage of this approach compared with that of Leta *et al* (2005) is that it allows one 'to see', through an index much like the standard DEA, the performance of each DMU related to its distance from the frontier of the worst practices.

Cross-multiplicative index

The 'cross-multiplicative index' approach consists of the normalized value obtained in the multiplicative version of the cross-evaluation technique. This multiplicative version is based on the geometric mean of the efficiencies obtained with all the different sets of weights, disregarding the weights that maximize the efficiency of the DMU under analysis. Expression (5) illustrates the calculation of this index.

$$E_k^{MCross} = \frac{\sqrt[h-1]{\prod_{\forall l \neq k} E_{lk}}}{\max\limits_k \left\{ \sqrt[h-1]{\prod_{\forall l \neq k} E_{lk}} \right\}} \tag{5}$$

wherein E_k^{MCross} represents the 'cross-multiplicative index' of a DMU_k; E_{lk} represents the efficiency of the DMU_k calculated with the weights that maximize the efficiency of the DMU_l; and h represents the number of DMUs analysed.

To get around the fact that the result of the cross-evaluation depends on the software used, since there may exist several sets of optimal weights of each DMU, two measures were taken: (a) the use of weight restrictions, which limit the scope of possible solutions to the units; and (b) the disposal, in the calculation of the cross-multiplicative index, of the weights of the DMUs, which were efficient in the standard efficiency, since these units typically possess a wider range of optimum possible solutions. Owing to the use of these two simple measures, highly computational expenses of the aggressive and benevolent models of cross-evaluation can be avoided.

Research variables

As input variable, the GDP per capita measured by PPP was adopted, because it was deemed to be a good indicator of a nation's economic wealth. These data were obtained from the IMF (2011).

As for the outputs in the studies reported in the literature, there is no standard when choosing social indicators, as shown in Table 5.

Considering that the choice of indicators is not only an academic issue, but also a political choice (Morais and Camanho, 2011), it was necessary to choose a theoretical insight regarding the concept of quality of life; thus, the approach by Sen (1999) was selected, which defines development as synonymous with freedom and is based on the concepts of 'functions' and 'capacity'.

With this backing, this study found that quality of life could be translated into long life with quality; good education; economic opportunities; minimum sanitary conditions; and living safely. Thus, social indicators regarding dimensions were selected: (a) longevity; (b) education; (c) socioeconomic; (d) inequality; (e) public safety; and (f) sanitary conditions. Ten outputs were selected from these dimensions: (1) Life Expectancy at Birth (LEB); (2) Child Mortality Rate (CMR); (3) Expected Years of Schooling (EYS); (4) Mean Years of Schooling (MYS); (5) Unemployment Rate (UR); (6) Inflation Rate (IR); (7) Gini Index (GI); (8) Women's Life Expectancy at Birth (WLEB); (9) Intentional Homicide Rate (IHR); and (10) Sanitation Rate (SR). Table 6 shows these indicators systematized and separated by size, and the respective sources from which the data were extracted.

Of all the indicators selected, the most important is undoubtedly Life Expectancy at Birth (LEB); in addition to summarizing within it a smaller number of indicators, there is no sense in talking about quality of life if death occurs prematurely (Sen, 1998). Another output for the question of longevity is the Child Mortality Rate (CMR), which is the predicted number of children who die before reaching the age of 5 years, per 1000 live births. It should be noted that, as it is an undesirable output, the model used the one thousand minus CMR, which is the result of a decreasing linear transformation (Seiford and Zhu, 2002), which can be interpreted as the number of children who survive more than 5 years, for every 1000 births.

As for the indicators related to education, two factors were used in the new method to calculate the HDI, namely, (a) Expected Years of Schooling (EYS), which is the expected number of years that a child will attend school, if the current enrolment rates by age are kept; and (b) Mean Years of

Table 5 Social variables used in the major works about composite social indexes

Authors	*Social variables*
Mahlberg and Obersteiner (2001); Despotis (2005a, b); Romero and Fortes (2007); Despotis *et al* (2009); Romero *et al* (2009); Bougnol *et al* (2010); Zhou *et al* (2010) and Tofallis (2013)	IDH indexes
Blancard and Hoarau (2013)	Longevity, education, sustainable standard living and carbon footprint
Chaaban (2009)	Youth unemployment rate; school dropout rate; fertility rate in adolescence
Fidalgo *et al* (2009) and González *et al* (2011a, b)	Unemployment; socioeconomic condition; pollution; commercial market share; lack of parks; cultural and sports facilities; lack of cleanliness; health facilities; acoustic pollution; education facilities; delinquency/vandalism; social care facilities; bad communications; average education level; time spent in journeys; post compulsory education; university studies; average net usable area; living conditions
Hashimoto and Ishikawa (1993); Hashimoto and Kodama (1997) and Hashimoto *et al* (2009)	Suicide rate; failure rate; number of crimes reported to the police; number of traffic accidents; GDP per capita; number of hospital beds, quality of the water; sanitation rate
Malul *et al* (2009)	GDP per capita and Gini Index
Martic and Savic (2001)	GDP; number of doctors; number of students in basic education; unemployment rate
Morais and Camanho (2011)	29 indicators about the dimensions: Demographic (3 indicators); social (7 indicators); economic (5 indicators); civic (1 indicator); education (3 indicators); environmental (4 indicators); transportation (2 indicators); informational (1 indicator); cultural (3 indicators)
Poveda (2011)	PIB per capita, Gini Index, unsatisfied basic needs; intentional homicide rate
Raab *et al* (2000)	Child Mortality Index; rate of child malnutrition; literacy rate of children
Ramanathan (2006)	Level of female illiteracy; child mortality rate; percentage of people dependent on the economically active population; unemployment rate; life expectancy at birth; GDP per capita; percentage of women enrolled in basic education
Somarriba and Pena (2009)	Satisfaction with standard of living; happiness; life satisfaction; home satisfaction; social life satisfaction; income; job satisfaction; health system satisfaction; living satisfaction area; health satisfaction; life expectancy at birth; unsafely; trust people; life expectancy at the age of 65; family satisfaction; expected years of schooling; employment; education satisfaction; leisure time; trust in judicial system; inequality; distance to school; stress

Table 6 Quality of life variables

Dimension	*Variable*	*Source*
Longevity	Life Expectancy at Birth (LEB) and Child Mortality Rate (CMR)	UNDP (2011) and World Bank (2011b)
Educational	Expected Years of Schooling (EYS) and Mean Years of Schooling (MYS)	UNDP (2011)
Economic	Unemployment Rate (UR) and Inflation Rate (IR)	CIA (2011) and IMF (2011)
Inequality	Gini Index (GI) and Women's Life Expectancy at Birth (WLEB)	CIA (2011) and World Bank (2011b)
Public safety	Intentional Homicide Rate (IHR)	UNDP (2011)
Sanitary conditions	Sanitation Rate (SR)	UNDP (2011)

Schooling (MYS), which is the average time a 25-year old attended school. It is emphasized that education has a dual role in the quality of life assessment, because while it is an important element of human capital, as an input to economic growth, it is also important in itself, since it increases the capacity of individuals (Sen, 1997; Baldacci *et al*, 2008).

The social indicators related to economic aspects were (a) Unemployment Rate (UR) and (b) Inflation Rate (IR). The unemployment rate represents the percentage of people who are looking for work within the EPA, but as this is an undesirable output (Seiford and Zhu, 2002) it was used subtracted from 100, which is an employment rate. The justification for using the UR as one of the outputs of the analysis is that the impact is much greater than only for economic reasons, also contributing to the 'social exclusion' of some groups, in addition to loss of autonomy, self-confidence and physical and psychological health (Sen, 1999).

As for IR, it was included in the analysis due to its social costs, which relate both to an expected inflation and to an unexpected inflation. Two important conditions should be mentioned with regard to the IR value that was adopted in the analysis: (1) as in some countries the IR usually exhibits much variation from one year to the next, it was deemed more interesting to adopt, instead of the data available for the last year, the average IR of the last 10 years; and (2) like unemployment, the IR is also an undesirable output, which meant that it needed to undergo a decreasing linear transformation (Seiford and Zhu, 2002), as shown in Expression (6):

$$IR^t = 30\% - |IR| \qquad (6)$$

Since there is no limit to a country's inflation, it should be noted that 30% was an arbitrary choice, which is slightly above inflation in Venezuela (22.5%), which presents the highest value among the countries analysed. With this choice, we tried to arbitrate a value that could guarantee that countries with high inflation were penalized, while at the same time the countries with low inflation were not affected due to very small alterations in this variable. Also noteworthy is the fact that in Expression (6) the IR was used in mode, which allowed the penalization of countries with deflation, since they also generate social costs for the population.

It matters little that a country has good social indicators if the distribution of these benefits among genders, races, social classes or regions is uneven; this significance was brought into focus by Grimm *et al* (2008), who stated that one of the major flaws commonly cited for HDI is not considering this distribution. As indicators for this issue, the Gini Index (GI), which measures income inequality, and Women's Life Expectancy at Birth (WLEB), which expresses gender inequality, were adopted.

A comment about the GI is that it only considers the income that comes from work, ignoring, for example, the financial yields. This limitation stems from the enormous difficulties in developing a distributional measure that could allocate the different groups of income flows from one individual (Stiglitz *et al*, 2009). Even so, this indicator was adopted, as it was regarded as providing important information about a country's income inequality.

Similarly, income inequality was considered, as it was deemed important to adopt an output that reflected gender inequality, which is found to be deeply rooted in several countries, particularly disadvantaging women. According to Sen (1999), nothing is as important today in economic development policies as the adequate recognition of women's political and economic leadership participation, and social status.

As indicator for public safety, the annual Intentional Homicide Rate (IHR) per 100 000 inhabitants was used, which despite its heterogeneous measurement forms provides a reasonable crime level indicator for a country. Since it is an undesirable output, the annual number of people who were not killed per 100 000 inhabitants was used in the analysis—in other words, 1 minus the IHR. The significance of considering public safety as one of the quality of life indicators can be corroborated by the 2011 HDR, whose central theme was worldwide violence (World Bank, 2011a). According to *The Economist* (2011), the main obstacle to development is no longer the poverty trap; it is now the violence trap.

Lastly, with regard to housing quality, the percentage of the population with access to sanitation (SR) was adopted in the analysis, which refers to the presence of effective excreta disposal facilities that can isolate waste from contact with humans, animals and insects.

Method

The method of this work can be systematized in the following steps: (a) identification and collection of data that characterize the countries' wealth produced and quality of life; (b) analysis of the variables and the time lag between inputs and outputs; and (c) determination of the countries' social efficiency and use of the tiebreaker methods to discriminate between them.

In the first step, a social and economic database of the countries, available for the last year, was created. The major reason for mixing the data from different years in the same cross-sectional analysis was the numerous data missing, which would preclude a more comprehensive analysis. We emphasize that this procedure has already been used by Somarriba and Pena (2009), which enabled them to compare a considerable range of countries.

In the second stage, a cross-sectional simple linear regression was used to determine the time lag between inputs and outputs, as well as to perform a pre-evaluation of the social indicators selected; to do this we used Gretl software. The time lag analysis was performed by simple linear regression between each output and the GDP per capita over the last 8 years (2000–2008), and the lag that best explained the largest number of variables was adopted. In the prior analysis of indicators, each variable of quality of life was analysed separately from its dependency relationship with the already lagged GDP per capita. At this stage it was found that the correlation matrix between the outputs verified the presence of redundant variables.

Finally, we used DEA, by means of the Frontier Analyst software, to find the countries' social efficiency, using an output-radial oriented model in order to increase the quality of life without reducing economic growth. The BCC model was chosen among these models, which is justified by the fact that countries with very different per capita incomes were analysed. Another justification for using the BCC model is that it fits better with the use of ratios as inputs or outputs (Hollingsworth and Smith, 2003), as in the case of this research. It is important to highlight that due to the fact that DEA produces many ties between efficient DMUs, four different methods were used to discriminate between them, (a) standard frontier; (b) cross-evaluation; (c) inverted frontier; and (d) 'triple index' with equal weights of 1/3, which were chosen because it was considered that all indicators should have the same importance for the triple index.

Also in relation to the models used, some restrictions were added to the weights, as it was important that no social variable was relegated to the background by assigning any country a very low weight. Among the types of weight restrictions, the 'Virtual output restrictions' (Wong and Beasley, 1990) were chosen due to their high practicality and ease of interpretation. The values defined for the relative weights of each variable are shown in Table 7.

The reason a minimum relative weight of 10% was chosen for the variable LEB, which is higher than that defined for all the other variables (5 and 7%), is that it makes no sense to address the other quality of life dimensions if they are prematurely deceased (Sen, 1998). Assigning a minimum relative weight of 7% to the variables GI and WLEB can be explained by the fact that all the other variables selected refer to average indicators, and these are the only two variables that take into account a distributive approach, rather than aggregative, of social justice (Sen, 1999).

Table 7 Weight restrictions

Variable	*Minimum relative weight to virtual output (%)*
Life Expectancy at Birth (LEB)	10
Women's Life Expectancy at Birth (WLEB)	7
Gini Index (GI)	7
Expected Years of Schooling (EYS)	5
Mean Years of Schooling (MYS)	5
Child Mortality Rate (CMR)	5
Sanitation Rate (SR)	5
Intentional Homicide Rate (IHR)	5
Unemployment Rate (UR)	5
Inflation Rate (IR)	5

Preliminary analysis of the variables

This section presents the results of the prior analysis of input and output variables, which comprises (a) evaluation of the time lag between the GDP per capita and the outputs; (b) statistical analysis of the relationship between the GDP per capita, already outdated, and the social variables; and (c) analysis of the correlation matrix of the outputs.

In the time lag analysis, each output was analysed by means of simple linear regression from its relationship with the 2000–2008 GDP per capita. After comparing the Schwarz criterion of some econometric models (linear, log-log, log-linear and polynomial), we decided to use a log-log model, that is, the logarithms for GDP per capita as well as the social variables were adopted, hence obtaining the model shown in Expression (7).

$$\text{Social Variable} = \beta_0 \times (\mathit{GDP}\ \text{per capita})^{\beta_1} \qquad (7)$$

Before applying the regressions, the White test was performed to verify whether it had the presence of heteroscedasticity. The test demonstrated that there was heteroscedasticity in the variables EYS, LEB, MYS, SR, UR and WLEB. To avoid this problem, we used the heteroscedasticity-corrected linear model in the Gretl software. Table 8 shows the Schwarz criterion obtained with this model in each of the 90 regressions performed.

Table 8 indicates that, even though there is little variation in the Schwarz criterion, for 3 of the 10 outputs adopted, the 2004 GDP per capita presented the best linear function fit. In addition, 2004 also had the lowest average of the Schwarz criterion and the lowest sum of the rankings between different variables, which reinforces choosing this year as a good time lag. Thus, considering most of the social data referring to 2008 or 2010 (even if there were data mixed from other years), it can be estimated that the average time for per capita wealth to be converted into social benefits tends to vary between 4 and 6 years.

Table 8 Schwarz criterion of output variables in terms of GDP per capita

Year of GDP	*CMR*		*EYS*		*GI*		*IHR*		*IR*	
	Value	*Rank*	*Value*	*Rank*	*Value*	*Rank*	*Value*	*Rank*	*Value*	*Rank*
2000	411.55	6	445.81	3	414.45	3	409.99	4	425.95	8
2001	409.05	4	442.5	2	412.25	1	407.83	1	430.79	9
2002	413.21	8	455.02	7	414.85	4	409.71	2	421.64	7
2003	411.65	7	447.75	4	415.54	6	411.53	6	416.67	5
2004	409.33	5	440.69	1	413.91	2	409.80	3	414.30	2
2005	400.13	1	454.97	6	415.35	5	412.29	7	415.71	4
2006	401.41	2	456.45	8	416.90	8	414.43	9	414.32	3
2007	413.53	9	460.2	9	416.35	7	413.10	8	413.98	1
2008	406.99	3	451.65	5	419.47	9	410.46	5	419.42	6
Best year	2005		2004		2001		2001		2007	

Year of GDP	*LEB*		*MYS*		*SR*		*UR*		*WLEB*		*Mean of Schwarz criterion*	*Sum of ranking positions*
	Value	*Rank*	*Value*	*Rank*	*Value*	*Rank*	*Value*	*Rank*	*Value*	*Rank*		
2000	488.7	9	426.53	1	372.05	4	459.07	8	490.18	9	434.43	55
2001	471.39	5	440.21	7	371.15	2	461.56	9	482.33	5	432.91	45
2002	462.55	3	434.15	4	368.92	1	454.91	7	471.76	1	430.67	44
2003	461.34	2	440.59	8	371.24	3	454.27	6	474.69	2	430.53	49
2004	457.57	1	439.26	6	374.46	5	452.34	1	475.51	4	428.72	30
2005	463.93	4	443.71	9	377.71	6	454.15	5	475.46	3	431.34	50
2006	486.07	8	434.01	3	388.83	7	452.72	2	484.19	7	434.93	57
2007	475.43	7	433.99	2	408.58	9	453.69	4	482.77	6	437.16	62
2008	473.41	6	436.08	5	407.23	8	452.84	3	485.92	8	436.35	58
Best year	2004		2000		2002		2004		2002		2004	

Table 9 Coefficient, p-value and adjusted R^2 value of output variables in terms of GDP per capita

Variable	*Coefficient* (β_1)	*p-value*	*Adjusted* R^2 *value*
Child Mortality Rate (CMR)	−0.86	< 0.00001	0.80
Expected Years of Schooling (EYS)	0.15	0.00002	0.65
Gini Index (GI)	−0.06	0.00002	0.16
Inflation Rate (IR)	−0.38	< 0.00001	0.41
Intentional Homicide Rate (IHR)	−0.43	< 0.00001	0.17
Life Expectancy at Birth (LEB)	0.06	< 0.00001	0.46
Mean Years of Schooling (MYS)	0.17	< 0.00001	0.37
Sanitation Rate (SR)	0.10	< 0.00001	0.33
Unemployment Rate (UR)	−0.20	0.01483	0.05
Women's Life Expectancy at Birth (WLEB)	0.06	< 0.00001	0.42

Table 10 Correlation matrix between the outputs

	CMR	*EYS*	*GI*	*IHR*	*IR*	*LEB*	*MYS*	*SR*	*UR*	*WLEB*
CMR	1.00									
EYS	−0.75	1.00								
GI	0.27	−0.38	1.00							
IHR	0.02	−0.14	0.51	1.00						
IR	0.31	−0.41	0.14	0.33	1.00					
LEB	−0.88	0.73	−0.38	−0.13	−0.45	1.00				
MYS	−0.67	0.80	−0.42	−0.18	−0.34	0.63	1.00			
SR	−0.78	0.65	−0.37	−0.06	−0.33	0.74	0.59	1.00		
UR	0.50	−0.41	0.17	−0.04	0.00	−0.50	−0.38	−0.35	1.00	
WLEB	−0.91	0.75	−0.40	−0.10	−0.41	0.99	0.66	0.77	−0.51	1.00

After defining the time lag, we evaluated the relationship between each output and the lagged GDP per capita. Table 9 shows the results of the coefficients, the adjusted R^2 and the p-values of the ANOVA of the regressions of each output, and the 2004 GDP per capita.

By analysing the adjusted R^2 values, which express the quality of the variables adjusted to a logarithmic function, it was observed that most of the outputs did not display a good fit, which indicates that GDP per capita is a variable that cannot alone explain all social indicators. Therefore, it should be noted that the variables best explained only by GDP per capita were Child Mortality Rate (80%), Expected Years of Schooling (65%) and Life Expectancy at Birth (46%). On the other hand, the variables least explained only by GDP per capita were Unemployment Rate (5%), Gini Index (16%) and Intentional Homicide Rate (17%).

Table 9 shows that all p-values of the ANOVA were less than '0.05', which indicates that for a confidence level of 95%, all variables have a dependency relationship with GDP per capita, which qualifies them to be used in DEA. Yet it is possible that these estimators may have been distorted by the presence of specification bias, since simple regressions were used, as all signs of the coefficients showed results in line with the expectations, which decreases this possibility.

According to the analysis of the results in Table 9, the theory is corroborated by stating that economic growth is a necessary condition (due to the low p-values of ANOVA), but not sufficient (due to the low adjusted R^2 value for some variables) for the occurrence of human development.

Another analysis carried out was the construction of the correlation matrix between social indicators, shown in Table 10, in order to verify the presence of redundancy between these variables.

Some correlation coefficients, as shown in Table 10, were increased, with the highest redundancy indications found among the variables LEB, WLEB and CMR; and yet the *output* least related to the other social variables was IHR. It should thus be emphasized that despite the presence of redundancies, it was decided to keep all the variables in the analysis, as it was considered that all embody important informational bases.

It is worth noting in relation to the variables WLEB and LEB that despite the quite high correlation there is a difference between them, which varies from country to country and normally is about 1–5 years in favour of women. For some countries, such as Namibia, Cameroon, Pakistan, Kenya, Swaziland and Nepal, however, female life expectancy is below average, which can be observed in Table 11, representing an unfavourable situation of the female population. After discarding the possibility of including the difference between WLEB and LEB as a variable, since this would give more weight to the countries where women live longer than men, such as Kazakhstan, Russia and Belarus, it was decided to maintain the two variables in the analysis, since, although correlated, they possess an complementing explanatory effect. This fact was proven when the variable WELB was

Table 11 Differences between WLEB and LEB

Greatest differences	*Countries*	*Life expected of birth of women (WLEB)*	*Average life expected of birth (LEB)*	*Difference*
Negative	Swaziland	45.11	46.97	−1.86
	Kenya	54.66	55.56	−0.90
	Pakistan	66.86	67.16	−0.30
Positive	Kazakhstan	72.48	65.36	7.12
	Russia	74.16	67.21	6.95
	Belarus	76.56	69.63	6.94

excluded from the analysis, which generated the effect that the social efficiency of countries with gender inequality increased by about 10% (wrongly, in our view), while the values of the other countries remained virtually unchanged.

Results

Table 12 presents the countries' social efficiency results obtained from (a) standard frontier (E_{kk}); (b) inverted index (E_k^{inv}); (c) cross-multiplicative index (E_k^{Mcross}); and (d) triple index (E_k^{Triple}) with equal weights of 1/3. Note that all

Table 12 Social efficiency of countries

Country	E_{kk}		E_k^{MCross}		E_k^{inv}		E_k^{Triple}	
	Index	*Position*	*Index*	*Position*	*Index*	*Position*	*Index*	*Position*
Armenia	100	1	100.00	1	99.66	2	100.00	1
Montenegro	100	1	94.86	10	100.00	1	98.37	2
Albania	100	1	95.83	8	98.70	3	98.27	3
Jordan	99.49	6	95.80	9	95.99	11	97.19	4
Georgia	100	1	96.76	5	94.25	20	97.09	5
Tajikistan	100	1	97.83	2	92.18	40	96.72	6
Kyrgyzstan	100	1	97.05	4	92.23	39	96.48	7
Moldova	100	1	96.73	6	92.51	35	96.47	8
Vietnam	100	1	95.94	7	91.75	44	95.94	9
Uzbekistan	100	1	97.12	3	90.54	56	95.91	10
Tunisia	97.94	25	92.25	14	95.93	13	95.45	11
Poland	99.75	3	88.28	35	98.24	4	95.39	12
Peru	98.14	22	92.76	12	95.00	16	95.38	13
Belarus	100	1	90.51	23	94.22	21	94.94	14
Bosnia and Herzegovina	97.08	31	91.21	19	95.94	12	94.82	15
Philippines	97.93	26	94.42	11	91.71	45	94.76	16
Uruguay	99.75	4	90.11	27	94.27	19	94.74	17
Ukraine	100	1	92.55	13	91.00	53	94.54	18
Algeria	96.49	35	90.26	25	96.20	10	94.38	19
Hungary	100	1	86.03	44	96.67	9	94.15	20
The Czech Republic	100	1	84.90	50	97.26	5	93.92	21
Estonia	100	1	86.18	42	95.63	14	93.86	22
South Korea	100	1	84.36	55	97.05	6	93.66	23
Malta	100	1	83.98	56	96.98	7	93.49	24
Croatia	98.41	17	85.52	46	96.77	8	93.49	25
Bulgaria	97.97	23	89.03	31	93.32	30	93.47	26
China	95.38	43	92.22	15	92.10	41	93.33	27
Morocco	94.53	48	91.90	17	93.13	31	93.29	28
Serbia	97.01	33	88.76	33	93.92	25	93.27	29
Kazakhstan	98.62	14	89.03	32	91.90	43	93.20	30
Malaysia	97.95	24	87.43	37	93.98	24	93.12	31
Azerbaijan	96.22	39	91.31	18	91.06	51	92.94	32
Macedonia	95.95	40	88.63	34	93.72	28	92.82	33
Ecuador	96.26	38	90.65	22	91.31	50	92.81	34
Bangladesh	100	1	90.33	24	88.15	66	92.79	35
Chile	97.46	28	87.48	36	92.54	34	92.51	36
Indonesia	94.36	50	90.69	21	92.10	41	92.48	37
Thailand	95.07	46	89.94	28	90.70	55	91.98	38
Latvia	96.52	34	85.50	47	93.76	27	91.91	39
Slovenia	99	9	81.73	64	95.44	15	91.85	40
Sri Lanka	96.33	37	91.99	16	86.84	72	91.74	41
Mongolia	97.31	30	90.17	26	87.66	68	91.73	42
Egypt	94.24	52	89.87	29	90.82	54	91.73	43
Israel	99.21	7	81.21	67	95.00	16	91.58	44

Table 12 *Continued*

Country	E_{kk}		E_k^{MCross}		E_k^{inv}		E_k^{Triple}	
	Index	*Position*	*Index*	*Position*	*Index*	*Position*	*Index*	*Position*
Argentina	97.46	29	86.59	41	90.16	59	91.39	45
Portugal	97.84	27	81.83	63	94.83	18	91.33	46
Australia	100	1	79.59	69	94.04	23	90.90	47
Paraguay	93.59	54	90.88	20	87.50	69	90.72	48
Japan	100	1	79.12	70	93.80	26	90.64	49
Mauritius	94.24	53	85.21	49	92.33	37	90.61	50
Greece	98.38	19	80.02	68	94.16	22	90.60	51
Panama	94.46	49	86.60	40	90.05	60	90.42	52
Germany	100	1	78.62	74	93.58	29	90.38	53
Nicaragua	94.66	47	89.38	30	86.66	74	90.28	54
Finland	99.7	5	78.06	77	92.51	35	89.73	55
France	98.97	11	78.27	75	92.88	32	89.71	56
Spain	98.17	20	78.70	72	92.78	33	89.60	57
Cambodia	95.34	44	87.22	39	85.89	77	89.49	58
Sweden	100	1	77.09	79	92.31	38	89.38	59
Costa Rica	95.57	42	85.26	48	86.78	73	89.19	60
Mexico	94.26	51	83.74	58	89.40	61	89.13	61
Turkmenistan	91.18	60	86.17	43	88.13	67	88.57	62
The Netherlands	99	10	76.03	82	91.44	48	88.39	63
Belgium	98.39	18	76.34	80	91.46	46	88.34	64
Denmark	98.56	15	76.09	81	91.46	46	88.29	65
Austria	98.71	13	75.44	84	91.36	49	88.05	66
Canada	98.55	16	75.73	83	91.02	52	88.00	67
Brazil	92.28	57	84.74	52	86.53	75	87.89	68
Turkey	92.38	56	82.16	61	89.07	62	87.86	69
Dominican Republic	90.74	61	85.76	45	86.20	76	87.64	70
Russia	93.34	55	82.27	60	86.87	71	87.47	71
Switzerland	98.83	12	74.56	85	90.39	57	87.43	72
Nepal	99.87	2	81.37	66	81.53	81	87.28	73
Iceland	98.15	21	74.10	88	90.36	58	87.04	74
Ireland	99.15	8	74.02	89	88.83	65	86.81	75
Norway	100	1	73.04	91	88.96	64	86.71	76
India	88.2	64	84.64	53	86.89	70	86.66	77
United Kingdom	96.39	36	74.40	87	88.98	63	86.19	78
El Salvador	91.47	59	87.33	38	79.46	87	86.04	79
Colombia	89.66	62	83.89	57	81.28	83	84.97	80
Bolivia	88.13	65	84.89	51	80.24	86	84.45	81
Senegal	88.57	63	78.19	76	84.09	80	83.60	82
Pakistan	87.94	66	81.85	62	80.56	85	83.48	83
United States	95.93	41	69.74	97	84.78	78	82.87	84
Cameroon	87.9	67	77.98	78	80.92	84	82.25	85
Singapore	95.14	45	68.97	98	84.32	79	82.19	86
Guatemala	85.7	70	83.59	59	75.24	89	81.47	87
Yemen	80.86	73	81.40	65	81.37	82	81.30	88
Honduras	86.07	68	84.61	54	73.48	91	81.28	89
Mozambique	100	1	72.46	93	73.48	91	81.14	90
Jamaica	85.71	69	78.69	73	73.48	91	79.23	91
Ghana	84.45	71	78.89	71	73.48	91	78.90	92
Kenya	81.71	72	74.52	86	77.03	88	77.78	93
Venezuela	80.64	74	73.65	90	73.48	91	75.94	94
Luxembourg	97.07	32	60.15	100	73.48	91	75.51	95
South Africa	78.27	75	72.02	94	73.48	91	74.63	96
Namibia	76.93	76	72.98	92	73.48	91	74.53	97
Swaziland	76.18	77	70.96	95	73.79	90	73.70	98
Qatar	92.04	58	55.46	101	73.48	91	72.20	99
Burkina Faso	64.54	78	63.83	99	73.48	91	67.22	100
Nigeria	56.72	79	70.03	96	73.48	91	66.41	101

calculations were performed already taking into account the weight restrictions.

It is emphasized that the classification of the countries, presented in Table 12, cannot be considered a ranking in the formal sense, since the countries are being compared by different sets of weights. However, the procedure realized to classify the countries' efficiency does not contradict the theoretical assumptions of the DEA technique, which requires that the efficiency of a DMU be evaluated based on the set of weights that most favours its efficiency, also being open to the possibility to include restrictions on these weights. Therefore, the ordination shown in Table 12 should be analysed with appropriate care and may not be directly compared with a ranking provided by indexes using fixed weights, such as the HDI.

General comments about the triple index

Table 13 shows a correlation matrix in terms of the indices, as well as in terms of the placing of each country, regarding standard efficiency, inverted index, cross-multiplicative index and triple index.

As shown in Table 13, the high correlation levels prove that the triple index satisfactorily aggregates the three points of view analysed—both in terms of the indices themselves and in terms of the position of the countries. It is also noteworthy that the lowest correlation was between the classification of the standard frontier and the triple index, which is due to the fact that there are many DMUs on the frontier in the standard index. Table 13 also proves, by the somewhat lower correlation levels between them, that the standard, cross-multiplicative and inverted indexes are different enough to justify the construction of an aggregated index.

Table 13 Correlation matrix between the indexes

	Indexes				*Position*			
	E_{kk}	E_k^{MCross}	E_k^{inv}	E_k^{Triple}	E_{kk}	E_k^{MCross}	E_k^{inv}	E_k^{Triple}
E_{kk}	1.00				1.00			
E_k^{MCrss}	0.42	1.00			0.30	1.00		
E_k^{inv}	0.76	0.59	1.00		0.72	0.49	1.00	
E_k^{Triple}	0.82	0.83	0.90	1.00	0.67	0.85	0.84	1.00

Another analysis performed was related to the robustness test of the triple index for weights (α, β and γ) chosen for weighting the three indices that were aggregated. To perform this analysis, 500 sets of weights α, β and γ were randomly generated with Microsoft Excel. Table 14 shows the three countries most affected and the three least affected by changes in the weights used in the triple index.

As shown in Table 14, the countries most affected by the weight changes were those with the highest HDI, such as Norway, Sweden and Germany. This can be explained by the fact that these countries tended to have good results in standard frontier and very bad results in inverted and cross-multiplicative indexes. However, the countries least affected by the weight changes were those in the first and last positions of the triple index with equal weights. Although some countries were, in extreme cases, greatly affected by the set of weights used, the average standard deviation of countries in terms of their position was of 6.7 places and the mean amplitude was of 31.88 places, hence classifying the triple index as robust for the weights used.

Another evaluation of the robustness level of the triple index was performed based on a sensitivity analysis, which sought to verify what happened with this index when each output was removed from the model. Table 15 systemizes the results of this analysis, analysing the positive and negative changes in the countries' positions.

As shown in Table 15, the average triple index increased when the variables CMR, GI, IR, LEB, MYS, SR and UR were removed from the analysis. This means that these variables, due to how the triple index was built, functioned as a limiting factor for the efficiency of a number of countries, which explains why these variables receive greater attention.

In terms of changes in the countries' positions, the highest were for El Salvador and Turkmenistan, which rose in their place when the variables IHR and UR, respectively, were removed from the analysis. At both extremes, on the other hand, the changes were slight, with Armenia in first place in all situations, and the last place alternating between Nigeria and Burkina Faso.

Note that the average place changes (in proportions) when any of the variables were removed was of 3.73 places, a fact that enables the classification of the triple index as robust for the removal of a variable. In individual terms, the smallest changes were for the removal of the variable WLEB (average of 1.30 places) and the greatest change was for the removal of the variable IR (average of 5.80 places).

Table 14 Analysis of the robustness of triple index to changes in the weights

	Countries	*Best position*	*Worst position*	*Amplitude*	*Standard deviation of the positions*	*Position mean*
More affected	Norway	29	90	61	10.66	72.91
	Sweden	19	79	60	11.76	56.27
	Germany	15	71	56	12.18	48.77
Less affected	Armenia	1	2	1	0.22	1.05
	Burkina Faso	99	101	2	0.50	100.02
	South Africa	94	97	3	0.57	96.30

Table 15 Sensibility analysis of the triple index

	Triple index			*Greatest positive change*		*Greatest negative change*	
	Greatest	*Smaller*	*Mean*	*Country*	*Positions*	*Country*	*Positions*
All	Armenia	Nigeria	88.92				
(−)CMR	Armenia	Burkina Faso	89.39	Nigeria	+7	Sri Lanka	−11
(−)EYS	Armenia	Nigeria	88.79	Malaysia	+17	Mongolia	−25
(−)GI	Armenia	Nigeria	89.44	Thailand	+10	Bangladesh	−17
(−)IHR	Armenia	Nigeria	88.79	El Salvador	+52	Turkmenistan	−15
(−)IR	Armenia	Burkina Faso	89.47	Sri Lanka	+21	Morocco	−26
(−)LEB	Armenia	Burkina Faso	89.13	Kazakhstan	+10	Bangladesh	−14
(−)MYS	Armenia	Nigeria	90.90	Morocco	+21	Ukraine	−17
(−)SR	Armenia	Nigeria	89.80	Bolivia	+25	Turkmenistan	−16
(−)UR	Armenia	Nigeria	89.31	Turkmenistan	+39	Thailand	−15
(−)WLEB	Armenia	Nigeria	88.89	Thailand	+3	Sri Lanka	−6

Table 16 Efficiency results compared with state of the art

Author	*University*	*Social information*	*Efficient countries*
Results of this paper	World (101 countries)	10 indicators	Albania, Armenia, Australia, Bangladesh, Belarus, The Czech Republic, Estonia, Georgia, Germany, Hungary, Japan, Kyrgyzstan, Malta, Moldova, Montenegro, Mozambique, Norway, South Korea, Sweden, Tajikistan, Ukraine, Uzbekistan and Vietnam
Raab *et al* (2000)	Underdeveloped countries (38 countries)	Seven child quality of life indicators	Costa Rica, Chile, Jamaica and Uruguay
Despotis (2005a)	World (174 countries)	HDI indicators	Armenia, Azerbaijan, Canada, Cuba, Estonia, Georgia, Greece, Jamaica, Japan, Malawi, New Zealand, Sierra Leone, Solomon Islands, Spain, Sweden, Tajikistan, Tanzania, Ukraine, The United Kingdom and Yemen
Despotis (2005b)	Asia and Pacific (27 countries)	HDI indicators	Fiji, Hong Kong, Mongolia, Myanmar, Nepal, Philippines, Solomon Islands, South Korea, Sri Lanka and Vietnam

General comments about the performance of countries

Analysing only the standard frontier, it was noted that 23 of the 101 countries analysed were efficient: Albania, Armenia, Australia, Bangladesh, Belarus, the Czech Republic, Estonia, Georgia, Germany, Hungary, Japan, Kyrgyzstan, Malta, Moldova, Montenegro, Mozambique, Norway, South Korea, Sweden, Tajikistan, Ukraine, Uzbekistan and Vietnam. These 23 countries achieved maximum efficiency when they could adopt, given the restrictions previously established, the weights that most favoured them.

Some similarities can be found between efficient countries by the standard frontier, namely, (a) countries that have high social standards driven by a high per capita income, as is the case of Germany, Japan, Norway and Sweden; and (b) countries that were effective only because their input was extremely low (GDP per capita was less than US$1000.00), as is the case of Mozambique and Bangladesh. It was seen that the main common characteristic between these countries is the significant concentration, among the most efficient ones, of former Soviet republics and past socialist countries, especially from Eastern European countries, for example Armenia, Belarus, the Czech Republic, Estonia, Georgia, Hungary, Kyrgyzstan, Moldova, Montenegro, Tajikistan, Ukraine, Uzbekistan and Vietnam. It is noteworthy that the most inefficient countries by the standard frontier predominantly belong to southern Africa, such as South Africa, Namibia, Swaziland, Burkina Faso and Nigeria.

Before analysing other efficiency indices, these results should be compared with those of other studies, which are systematized in the State of the Art. Regarding this comparison, the following should be mentioned: (a) in all of the papers in the literature a more limited scope of social indicators than that adopted in this work was taken into account; (b) weight restrictions were not used in any of the papers; (c) no works have adopted a time lag between inputs and outputs; and (d) all the analyses found in the literature were only based on the standard frontier, and this study seems to be the forerunner in using tiebreaker methods to discriminate between countries. Table 16 presents the standard efficiency results, compared with those obtained by other authors who have studied the social efficiency of countries.

According to Table 16, the tendency of the most efficient countries with high income or a socialist past was repeated in several studies. However, some of the countries highlighted in these works could not partake in this analysis due to missing data. Similarly, there were countries, such as Mozambique and Bangladesh, both with low income per capita, that stood out only in this work, not appearing as efficient in any of the other works, which may have occurred because these countries were outside their research scope or because the indicators and weights used were different.

When the multiplicative cross-evaluation was performed, the first discrimination was performed between countries that were efficient by the standard frontier. This discrimination favoured countries with a more balanced efficiency, not depending on a single variable in order to be considered efficient. Thus, it can be stated that the greatest underachievers in this procedure were the wealthiest countries (Australia, Japan, Norway and Sweden had a cross-multiplicative index below 80%), rather than the poorest (the efficiency of Mozambique has significantly worsened). Moreover, Eastern European and former Soviet republic countries were consolidated in the first positions, especially Armenia, Tajikistan, Uzbekistan and Kyrgyzstan. As for the last positions, in addition to the southern African countries, which kept their low efficiency, four countries with high GDP per capita also showed poor performance: the United Sates, Singapore, Luxembourg and Qatar.

Analysing the efficiency obtained with the inverted frontier, which expresses the countries' distance to the frontier of the worst practices, it was observed that this frontier consists of Burkina Faso, Ghana, Honduras, Jamaica, Luxembourg, Mozambique, Namibia, Nigeria, Qatar, South Africa and Venezuela (all with inverted efficiency of 73.48%). It should be emphasized that the most efficient country by this method was Montenegro, followed by Armenia, Albania and Poland.

Consolidating all these analyses in a single value called 'triple index' it is possible to confirm the presence, in the top 20 positions, of a large number of former Soviet republics and Eastern European countries, with the greatest emphasis on Armenia (1st position), followed by Montenegro (2nd) and Albania (3rd). However, the negative results were for the southern African countries, especially South Africa (96th position), Namibia (97th), Swaziland (98th), Burkina Faso (100th) and Nigeria (101st), in addition to Qatar (99th), Luxembourg (95th) and Venezuela (94th).

Among the so-called BRICS, which are countries that are currently experiencing rapid economic growth, China (26th position), which also has a socialist history, stood out the most. It was seen that Brazil (68th position), Russia (71st) and India (77th) are positioned at the bottom of the list, with South Africa (96th) as one of the most inefficient countries. With regard to the Latin American countries, Brazil is at an intermediate position, behind Peru (13th), Uruguay (17th position), Ecuador (34th), Chile (36th), Argentina (45th), Paraguay (48th), Panama (52nd), Nicaragua (54th), Costa Rica (60th) and Mexico (61st), but ahead of the Dominican Republic (70th), El Salvador (79th), Colombia (80th), Bolivia (81st), Guatemala (87th), Honduras (89th), Jamaica (91st) and Venezuela (94th).

Among the G7 countries, all showed a performance between intermediary and weak, and the best results were presented by Japan (49th position) and Germany (53rd) and the worst by the United Kingdom (78th) and United States (84th). Developed countries, which often lead HDI rankings, such as Sweden (59th position), Denmark (65th), Canada (67th), Switzerland (72nd), Iceland (74th), Ireland (75th) and Norway (76th), had intermediate performance in social efficiency, indicating that despite being socially very well off, these countries could have had a much better performance, given their economic wealth.

Conclusions

There is, in empirical studies on quality of life, a clear trade-off between the number of countries analysed and the number of variables adopted. Thus, the present work sought a middle term, using a set of 10 social indicators (much more than taken into account in HDI), which enabled us to work with 101 countries. With this option, unfortunately and due to the lack of data, some countries were excluded that could provide interesting analyses, such as Cuba and North Korea, which are still socialist countries, or Afghanistan and Sierra Leone, which are extremely poor and politically unstable.

As for the group of social indicators used, it can be added that, although choosing them was justified based on the literature, this study did not intend to establish a definitive set of indicators on human development and much less on happiness, which begins to emerge as a promising research field, as can be seen in Jiang *et al* (2012). As already highlighted, quality of life has a multidimensional nature, making it a very difficult task to obtain a set of indicators that could encompass all the desires of a human being, which tend to be increasingly broader. It is believed that in the future, the databases provided by the international bodies will be larger and more all-inclusive, thereby enabling studies that can include a broader variety of social attributes than that used in this work, without this resulting in a great loss of countries to be analysed.

Regarding the analysis and characterization of the countries' social efficiency, it is believed that, with the triple index of the DEA, a satisfactory result has been reached. This positive result is reflected in the fact that a homogeneous group of efficient countries was obtained, which could provide clues about social efficiency, and which can be further studied in the future. One of these more relevant clues is the fact that the most efficient countries were the former Soviet republics and Eastern European and past socialist countries.

It is also important to mention that this work appears to be a pioneering one, among the few that have analysed social efficiency, with regard to using weight restrictions and tiebreaker methods related to DEA. The models used in this work represent only one sample of the many analyses possible in the literature, which could be used in future research to compare the results obtained. As other potential tools that could be used in this field, we can cite (a) the Malmquist index, which will enable the verification of the efficiency evolution of the countries over time; (b) the Artificial Neural Networks, which will enable the mathematical modelling of the relationship between the wealth produced and social development; and (c) scale efficiency, which will enable the incorporation into the analysis of the discussions on economic sustainable growth and degrowth.

Regarding the proposed triple index, it was concluded that it represents a robust index that has fulfilled its role of enabling the evaluation of the social efficiency of countries from different points of view. It is hoped that new applications and tests can be performed using this index in future work.

In short, we believe that this work has achieved its aim of introducing, organizing and evaluating a relatively new research field, which in this work was designated social efficiency. Notwithstanding, this work gives rise to questions about the results, and also regarding research opportunities, both in terms of new uses for the triple index and the application of new tools to assess the issue of social efficiency.

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