Data Envelopment Analysis in the Sustainability Context - a Study of Brazilian Electricity Sector by Using Global Reporting Initiative Indicators

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Abstract

A set of stakeholders (customers, employees, suppliers, public authorities, investors and others) pursuing different economic, environmental, and social interests determines the performance of an organization. In an effort to understand the corporate sustainability performance, this research focuses an analysis of sustainability indicators published in the reports of Global Reporting Initiative, disclosed by 24 Brazilian electricity sector in 2012. Indicators were identified and analyzed following: (i) a communication of economic, environmental, and social performance; and (ii) efficiency determined through the Data Envelopment Analysis (DEA) model. The results indicate that disclosures are often incomplete, and lack a pattern for similar indicators. Based on DEA, there is no direct relationship between economic value generated and distributed and efficiency, given that there are efficient large-scale hydroelectric plants and medium. In general, partial results are consistent with the conceptual assumptions that informal systems of enterprises promote sustainability, but their formal systems apparently have a very traditional focus on financial performance.

Keywords: Global Reporting Initiative; Data Envelopment Analysis; Triple Bottom Line; Brazilian electricity.

1. Introduction

Nowadays, electricity is one of the most important resources for the economic development of a country (Breeze, 2014). In addition, it is essential that two other factors are present at the same time to ensure that economic growth: afford energy access for the people as well as promote efficient use of natural resources (La Rovere et al., 2010). Brazil has been prominent in the international scenario due to the strong presence of renewable sources within its energy sector. Brazilian Energy Balance shows that such sources represented 41% of the country's domestic energy supply in 2013, whereas the world average was 13% and that of OCDE countries 8,1% (EPE, 2014).

According to Flórez-Orrego et al. (2014), electricity is not a primary energy source, and its generation efficiency and its emissions should be borne in mind in the conversion process, so that comparisons with other kind of energy resources could be done. In the case of power plants that still require burning fossil fuels to produce electricity, greenhouse gas emissions (GHG) are inherent to their operation. Moreover, while this sector serves as a motor of social and economic development, at the same time, it produces a high level of impacts around the world owing to fast depletion of non-renewable fuels, the global warming and the climate change (Lira-Barragan et al., 2014). Then, all types of production will have some effect, can be far-reaching both geographically and temporally.

Over the last years, the influence of the characteristics of specific industries on corporate sustainability have long been the focus of research (Chang et a., 2013). As well as, environmental (e.g. emissions, effluents, and waste) and social (e.g. diversity and equal opportunity) demands from stakeholders are contributing to the pressure for companies to consider sustainability issues more seriously. Today, sustainability is an important issue because of the mounting evidence to suggest that human activity in the Earth system is following an unsustainable trajectory observed over comparable time periods (IPCC, 2014).

In recent years there has been increased pressure on companies seeking to expand the focus to sustainability and responsible business performance in addition to financial performance (Leszczynska, 2012). Consequently, a number of voluntary tools, approaches, and initiatives have been developed by and for corporations to engage with sustainability. Some of the tools for sustainability include: cleaner production, corporate social responsibility, sustainability reporting, environmental management systems, corporate sustainability, and others approaches. For companies, the major challenge is to demonstrate its contribution to the society without compromising the future generations for a better quality of life (Singh et al., 2007). While there seems to be considerable consensus that a more sustainable society is in the best interest of everyone, opinions regarding what sustainability really means and how to achieve it are as diverse as the entities striving for it (Lindsey, 2011). For example, Sartori et al. (2014) argue that there has been lot of literature devoted to the subject, and no doubt a blurring of focus, as well as, the term sustainability is used, but little explained.

There are no universally agreed-upon approaches of measuring corporate sustainability, but it is clear that corporations must define and measure sustainability performance if they wish to be a source of value creation (Lopez et al., 2007). Monitoring progress towards sustainable development requires the identification of indicators that provide manageable units of economic, environmental and social conditions (Bohringer and Jochem, 2007). An example of the incorporation of sustainability in business practices is the growing number of sustainability reporting. Currently, the Global Reporting Initiative (GRI) is considered to be a global standard of sustainability reporting and widely used in the world (Roca, Searcy, 2012). Currently, Brazil is the third country in the world in number of companies publishing sustainability reports (GRI, 2012).

In this research, importance is given to quantitative methods to evaluate the corporate sustainability performance. The quantification of sustainability can create a common ground for comparing alternative policies (Kharrazi et al., 2013), as well as, operationalize the concepts and definitions of sustainability. According Maxim (2014), quantifying the level of sustainability is done through sets of evaluation variables which are generally called sustainability indicators. Moreover, as the main objective, this work seeks to assess the performance in 24 companies that work in the electricity sector and operate at Brazil, and use sustainability indicators as the GRI reporting. Besides this introduction, the paper is organized in three other sections: Literature Review, Methods, Results and Discussions, and Conclusions.

2. Literature Review

Sustainable development has become a motto for international aid organizations, a slogan for environmental and development activists, the jargon of heads of state, the subject of conferences and academic research (Lélé, 1991). Although seen as a fashion accessory (Hasna, 2010) or common sense (Moldan et al., 2012), there is no doubt that sustainable development is now a very dominant theme (Bell and Morse, 2008). Then, the challenge in sustainability performance evaluate is in developing a shared understanding of what sustainability means in the context of the corporation (Searcy, 2009). This is because that the concept of sustainability included a variety of meanings and different interpretations given to it by social and natural scientists (for example, sociologists, economists and ecologists) (Gerdessen and Pascucci, 2013).

The sustainability could be interpreted as 'adopting business strategies and activities that meet the needs of the enterprise and its stakeholders while protecting, sustaining, and enhancing the human and natural resources that will be needed in the future' (IISD, 1992). Sustainability means the ability to sustain or a state that can be maintained at a certain level (Hasna, 2010). In recent years, it has become common to represent sustainability by a Triple Bottom Line (Elkington, 1994), in which, the evaluate performance is defined as simultaneously achieving the economic, social, and environmental dimensions. The economic performance reflects organizational success in the market and to shareholders; environmental performance shows compliance with government legislation and administration for a group of environmentally conscious customers; social performance shows stakeholder management, especially with the work force and the local community (Sridhar, 2012).

The people have different ideas on sustainability in different contexts and as a result, solutions tend to be sustainable within sectors rather than across the whole of society (Kajikawa, 2008, p. 218). For example, there are distinct field of application (engineering, economics, management, ecology), in which each science tends to see only one side of the equation, however they are common, as they turn to sustainability (Sartori et al., 2014). According Bell and Morse (2008, p.110), in understanding sustainability we need to recognize and work with unities, of which we, as observers, are also part. In spite the humans should not focus on the sustainability of isolated entities, but rather on the sustainability of entities as interconnected parts of a wide, is necessary within each area, a range of context-specific sustainability definitions, goals, and indicators etc.

From the understanding of what sustainability performance really is it is necessary to define which indicators would represent it. Then, these indicators should respond to the policies, strategies and goals of the organizations according to their business area. Sustainability reports are the primary mechanism through which corporations share information on their sustainability performance (Searcy and Elkhawas, 2012) through a wide set of indicators. At present, the Global Reporting Initiative (GRI) is the leading standard in sustainability reporting and widely used in the world (Roca and Searcy, 2012). GRI is a nonprofit international institution, composed by a stakeholder network. GRI's mission is to make sustainability reports as routine as financial reports and safeguard the guidelines and its production process, as well as, to increase the reports' quality at a comparison, consistency and availability level (GRI, 2012).

Sustainability performance evaluation does not end with development selection of performance indicators (Staniškis and Arbačiauskas, 2009). In this sense, some kind of tool to organize different existing systems of indicators is needed. Because quantitative methods help to clarify and refine the concepts related to sustainability and improve the understanding of the complex relationships between the components of sustainability in practical terms (Wu and Wu, 2012). Among the various quantitative methods for decision support, it is mentioned: Analytic Hierarchy Process-AHP, Prométhée and Data Envelopment Analysis.

Data Envelopment Analysis (DEA) is a tool to evaluate the efficiency of decision-making units (DMUs), introduced by Charnes et al. (1978) on three decades ago, in which, is a linear programming procedure for a frontier analysis of inputs and outputs. This model is able to evaluate the performance quantitatively and qualitatively, permitting judgments about the efficiency of resource use (Wong and Wong, 2008). The efficiency score for each DMU is defined as a weighted sum of outputs divided by a weighted sum of inputs, where all efficiencies are restricted to a range from 0 to 1 or from 0% to 100% (Cooper et al., 2011).

In order to avoid potential difficulties in assigning these weights between the various DMU, a DEA model computes weights that give the highest score in relation to a DMU while keeping the efficiency scores of all DMUs less than or equal to one under the same set of weights (Liu et al., 2000). The concept of efficient frontier analysis forms the basis for the evaluation of DEA performance units, since it takes into account the best value that can be obtained from the data set, and it is not based on the average value (Wong and Wong, 2008). Therefore, DEA shows how a unit is effective in the treatment of their inputs and outputs in relation to the other (Cooper et al., 2011).

There are two basic models of DEA. The first model is called CCR (short for Charnes, Cooper and Rhodes, surnames of the authors, 1978), also known as CRS (Constant Returns to Scale) it evaluates the overall efficiency, identifies the efficient and inefficient DMUs and determines how far from the efficient frontier the inefficient units are. The second model is called BCC model (short for Banker, Charnes and Cooper, surname of the authors, 1984), also known as VRS (Variable Returns to Scale) it uses the dual formulation, which is commonly used in benchmarking. The main differences between the models are related (Wang et al., 2002): (i) the enveloping surface (combination types and assumptions about returns to scale); and (ii) the type of plan projection of the inefficient frontier.

This study identified and analyzed sustainability indicators published in GRI reports, considering that the electricity sector requires consideration of all three sustainability dimensions. Then, with the objective of assessment the performance of enterprise sustainability through quantitative methods, the DEA method was used through the analysis of sustainability indicators published in the GRI reports.

3. Methods

The empirical analysis proceeded in four main steps, as described below. At first step, the evaluation system and the content to be evaluated was defined, were considerate: (i) The environmental, economic and social dimensions; (ii) The positive and negative consequences of the business activity; (iii) the organizational environment; (iv) The national scale; and, (v) The use of GRI indicators, according standards G3.1 version.

In the second step, the identification of sample was made in the database of this organization (http://database.globalreporting.org/), for the reports referring to the year 2012. The total sample is composed by a group of companies from the electricity sector (generation, distribution and commercialization). The analysis of this sector is justified since, the energy sector is responsible for 17% of the Brazilian companies that publish reports based on the GRI model. Then, essential indicators were identified as reported in the summary pages, guaranteed the correct information and interpretation of the indicator. Data were compiled and tabulated in Microsoft Excel 2010 software and its description and analysis were performed using descriptive statistical. In order to safeguard the organizations, the name of the sample companies was maintained in anonymity.

In the third step, the indicators were identified following (i) a disclosure of economic, environmental, and social indicators and (ii) efficiency determined through the DEA model. For the use of DEA, the complete indicators were selected, i.e., variables with missing data or qualitative measures were omitted, making total of 15 indicators. After that, the analysis of correlation between these indicators was conducted to investigate the causal relationships and the existence of redundant information, three indicators were excluded. Then, the Principal Component Analysis (PCA) was performed in order to focus the minimum number of necessary factors to explain the maximum percentage of factors necessary to explain the maximum of the total variance represented in the original set of variables (Hair et al., 2009). Furthermore, it was observed the minimum ratio of three Decision Making Unit (DMUs) by variable (Ferreira, Gomes, 2009). The outputs and inputs are represented in Table 1.

Table 1 - Definition of the variables.

Variable	**Units**	**Indicators**
Output		
Y1	US$	Direct economic value generated and distributed
Y2	US$	Infrastructure investments and services provided for public benefit
Inputs		
X1	Gj	Direct energy consumption by primary energy
X2	km^2	Location and size of land owned, or adjacent to, protected areas and areas of high biodiversity value outside protected areas
X3	tCO2e	Total greenhouse gas emissions
X4	number	Total workforce
X5	rate	Rates of injury
X6	US$	Monetary value of fines for non-compliance with laws and regulations

DEA assumes that inputs and outputs are goods (Dyckhoff and Allen, 2001). But, this assumption is not valid when there are desirable inputs and outputs undesirable, or, inputs and outputs undesirable. Then, it is considered that: (i) inputs are the indicators that improve when their values decrease; and (ii) outputs are the indicators that improve when their values increase. The indicators of the type less is better are modelled as the inputs, and the indicators of the type more is better are modelled as the outputs (Sarkis, 1999).

According to GRI (2011): (i) the economic dimension of sustainability concerns to the organization's impacts on the economic conditions of its stakeholders and on economic systems at local, national and global level; (ii) the social dimension of sustainability concerns the impacts an organization has on the social systems within which it operates. For example, the indicators shows whether safety and health management practices are resulting in fewer incidents related to health and safety at work; and (iii) the environmental dimension of sustainability concerns an organization's impacts on living and non-living natural systems, including ecosystems, land, air, and water. In specific, the three environmental indicators will show the efficient use of energy, the efficient water use, the earth use and total emissions of greenhouse gases.

The DEA model represents the fourth step of the methodology. In this study, the main objective is to minimize the negatives impacts (represents by inputs) and to obtain the same level of positive value (represents by output). Initially, the DEA model was applied assuming constant scale returns, CSR, in order to obtain the technical efficiency measure for each company. Then, by adding a restriction convexity, obtaining the measurements efficiency with variable returns was made possible. With these two measures was possible to calculate the scale efficiency.

The measure of scale efficiency is calculated by dividing the measures of technical efficiency of the models with constant returns and variable returns, it indicates that: if the ratio is equal to 1, the company will be operating at optimal scale; if it is less than 1, the company is technically inefficient (Ferreira and Gomes, 2009). And the benchmark is determined by the projection of inefficient DMUs in the efficiency frontier (Appendix A). So, the higher the positive value of the do λ_k, more important is the efficient DMU as a partner of excellence, and the more often an efficient DMU is identified as a partner of excellence to the inefficient DMUs (Ferreira and Gomes, 2009).

4. Results

This section presents the results obtained in the research, in which initially it is presented the analysis of the indicators in the reports. To this, was compared the amount of indicators used by companies in each dimension relative to the total of core indicators available from GRI. Therefore, GRI suggests seven economic indicators, 17 environmental indicators and 26 social indicators, all core indicators. Core indicators are assumed to best capture the measuring of material aspects for most organizations (GRI, 2011). As Figure 1, only four companies (C, T, V and W) disclose more than 60% of the indicators in three dimensions.

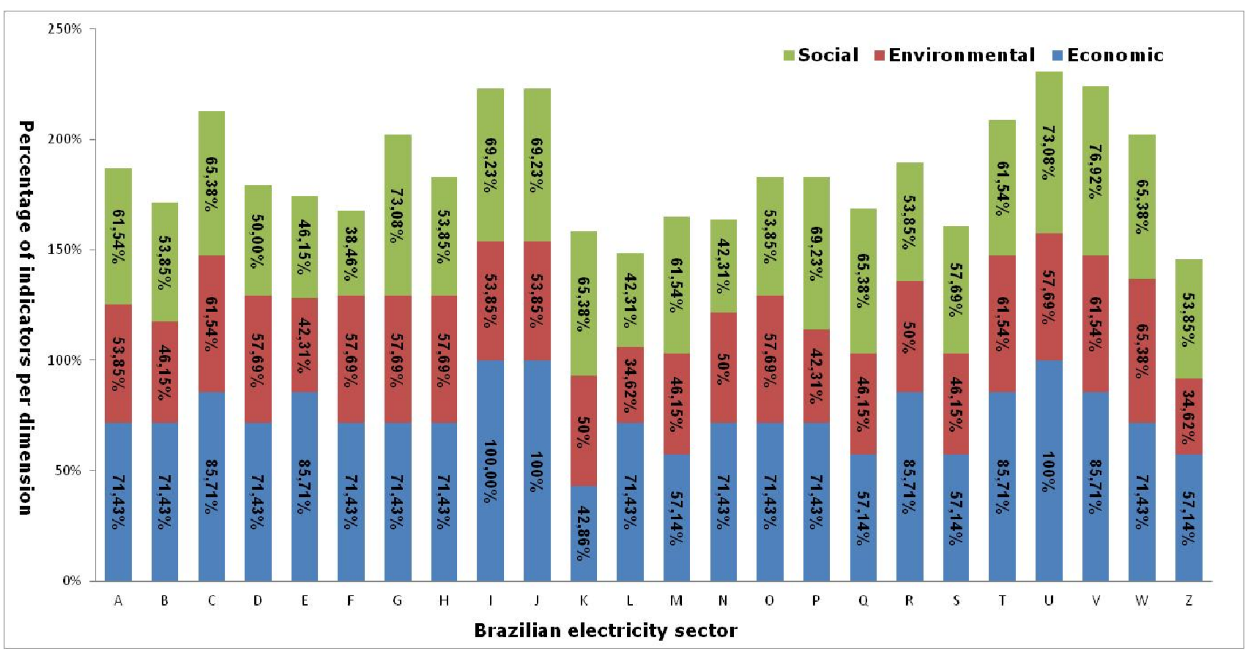

Figure 1 - Percentage of GRI indicators used by distributors in each dimension

There was preponderance in the use of economic indicators, ranging from 43% to 100% in the use of indicators proposed by the GRI. This condition can be associated with the fact that many of these indicators are already used in traditional financial reports. According Delmas and Blass (2010), the financial performance are well defined and very structured (for instance return on assets and return on investment), while social and environmental performance are quite heterogeneous.

The use of environmental and social indicators varies, respectively, from 35% to 65% and 38% to 78%. The results show that there are problems in the quality of information regarding the completeness, standardization and transparency of content, making it difficult to compare the performance of companies in relation to various aspects and sustainability indicators. Consequently, environmental, economic and social efficiency becomes reduced due to the total amount of data. The following discussion and analysis involve a descriptive analysis of the data, the application of DEA model and the presentation of the performance of indicators in relation to the Triple Bottom Line.

The set of indicators is represented by the descriptive measures in terms of average, minimum and maximum values and standard deviation, according to Table 1. Considering the sample of 24 companies for the year 2012, it is observed that the data refer to large companies because the lowest economic value generated and distributed was US$1.34+07. The indicators highlight were direct economic value generated and distributed, infrastructure investments and services provided for public benefit, financial implications for the organization's activities due to climate change and total direct energy consumption, which have higher average standard deviations, i.e., large dispersion.

Table 1 - Summary statistics of the indicators (2012)

Indicators	Mean	Minimum	Maximum	Std.Dev.
Y1	1.34E+07	5.89E+05	2.31E+08	4.65E+07
Y2	2.96E+07	5.24E+03	2.72E+08	6.86E+07
X1	2.22E+07	0.0	1.94E+07	5.57E+06
X2	8.71E+04	63.9E+01	5.68E+05	1.58E+05
X3	4.37E+05	1.61E+02	5.34E+06	1.14E+06
X4	3.28E+03	3.50E+01	9.47E+03	2.66E+03
X5	3	0	7	2
X6	4.25E+06	0.00E+00	4.74E+07	1.06E+07

Another differentiating factor between companies is the indicator employee turnover rate, considering the magnitude of the maximum and minimum values. The Table 2 presents an efficiency scale. The benchmarks results for the 24 studied organizations are presented in Appendix A. Considering the Constant Returns to Scale (CRS) model, 11 companies obtained the maximum technical efficiency. The average level of inefficiency is 0.442 (1-0.5580), i.e., that companies can, on average, reduce up to 44.20% the inputs (environmental and social indicators) without compromising economic indicators.

Considering the Variable Returns to Scale (VRS), was obtained a model with an average of 0.7213. Taking into account these returns, 13 companies have obtained technical efficiency measure equal to 1, therefore, they are models of efficiency for the set of companies analyzed. The condition for a company to submit the maximum technical efficiency with constant returns of scale, which is its technical efficiency, when considering variable returns, is also maximum. So, among the 13 companies with technical efficiency equal to 1 in VRS model, 11 companies of them are equally efficient in the model with constant returns.

The measure of scale efficiency (fourth column) indicates that sustainable companies are evaluated for their environmental-economic-social efficiency set by an efficiency score ranging from 0 to 1. If the indicator is equal to 1 the company is considered efficient because it is on the efficiency frontier, but below 1 it is inefficient because it is below the efficient frontier. It is noteworthy that 11 companies are on the border of constant returns, since the other 13 companies, although they are operating in the range of constant returns, they are not located on the efficient frontier. As highlight, the companies I, J and U had the worst efficiency scale, with increasing returns to scale, the variation in inputs results in changes that are more than proportional in the outputs. In this situation, the DMUs should rise their outputs, however, this increase must occur in order that relations between the used quantities of inputs are reduced.

Table 2 - Efficiency according to the CRS model (Technical Efficiency Score) and VRS model (Pure Technical Efficiency Score)

DMU	CRS	VRS	Scale Efficiency	RTS	DMU	CRS	VRS	Scale Efficiency	RTS
A	1	1	1	Constant	M	1	1	1	Constant
B	1	1	1	Constant	N	1	1	1	Constant
C	1	1	1	Constant	O	1	1	1	Constant
D	0.0029	0.0464	0.0618	Increasing	P	0.0186	0.1789	0.1042	Increasing
E	0.0317	0.3294	0.0963	Increasing	Q	1	1	1	Constant
F	0.0528	0.3943	0.1339	Increasing	R	1	1	1	Constant
G	0.6066	0.7363	0.8238	Decreasing	S	0.0338	0.5822	0.0581	Increasing
H	0.5572	1	0.5572	Increasing	T	1	1	1	Constant
I	0.0206	0.6354	0.0324	Increasing	U	0.009	0.2905	0.0311	Increasing
J	0.0142	0.5272	0.027	Increasing	V	0.4597	0.4687	0.9807	Increasing
K	1	1	1	Constant	W	0.5735	1	0.5735	Increasing
L	1	1	1	Constant	Z	0.0136	0.1217	0.1118	Increasing
Mean	0.5580	0.7213	0.6080						
Std.De	0.4544	0.3422	0.4408						

Also worth noting is the G company that features decreasing returns to scale, i.e., is operating above optimal scale, requiring only to improve technical efficiency, which is equivalent to increasing the outputs with the same inputs. In the case of G Company, it is proposed that the inefficiency is largely due to an excessive number of workers. The V Company obtained a score of 0.98, the nearest one from the efficiency frontier. The company just needs to keep constant the input indicators (e.g. energy consumption, area of operation, total employees) and increase the results (e.g., economic value generated and distributed).

In general, 45,8% of the companies do not present problems of inefficiency in the use of inputs and neither in the scale results. In the benchmarks analysis (Appendix A), the companies considered effective are referrals for the other companies considered inefficient. The companies L, N e M are considered the best partners of excellence for the inefficient DMUs, i.e., appear more as benchmarks. These three companies have no monetary value of significant fines for noncompliance with laws and regulations concerning the provision and use of products and services, lower headcount and higher infrastructure investments provided for the public benefit. Finally, the key point of the analysis is not to figure out what is best to operate with increasing or decreasing returns. Both returns have problems, i.e., the inputs are being used excessively. It is necessary that inefficient companies be aware that they can reduce or fix problems related to sustainability indicators (inputs), and at the same time, increase the company's value.

Finally, it is important highlight the boundary between sustainability and unsustainability is not clear, this means that it is not possible to determine accurate values of reference for sustainability (Azar et al., 1996), different from the process of quality control (example upper and lower control limits). The specification of a performance (upper and lower limits) can occurs through the specification of benchmarks for sustainability. A benchmark is a target value that the process or product must meet (Joung et al., 2013). Thus, one of the biggest benefits of using DEA is the set of reference units that can be used as benchmarking in improving the performance of less efficient units.

5. Conclusions

The environmental, economic and social relevance of the electricity sector is related to the increasing demand for energy to sustain current rates of the development, as it is the case of Brazil. This empirical research reveals that the same sector have significant differences in sustainability performance; the average scale efficiency is around 61% for the sample, requiring a significant improvement in the use of resources (inputs); the economic dimension prevails in results released through sustainability reports, with coverage above 80% in 5 companies. Future research can be made about the potential causes of the incomplete or low transparency reports. As well as, it is pertinent to evaluate a larger group of companies of other sectors and countries, as well as a larger number of indicators. As a limitation, it is emphasized that the companies are classified as efficient within the rated range, which may not necessarily be efficient to evaluate a larger set of companies in the studied sector.

References

Bell, S., Morse, S. (Eds.), 2008. Sustainability indicators: measuring the immeasurable? London, Earthscan.

Bohringer, C., Jochem, P.E.P., 2007. Measuring the immeasurable - A survey of sustainability indices. Ecological Economics. 63, 1-8.

Breeze, P., 2014. Power Generation Technologies. Second Edition: Elsevier, London

Chang, D.S., Kuo, L. R., Chen, Y., 2013. Industrial changes in corporate sustainability performance e an empirical overview using data envelopment analysis. Journal of Cleaner Production. 56, 147-155.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European journal of operational research. 2(6), 429-444.

Cooper, W.W., Seiford, L.M., Zhu, J., 2011. Handbook on data envelopment analysis. 2º Ed., Springer New York Dortrecht, London.

Delmas, M., Blass, V.D., 2010. Measuring Corporate Environmental Performance: the Trade-Offs of Sustainability Ratings. Business Strategy and the Environment. 19, 245–260.

Dyckhoff, H., Allen, K., 2001. Measuring ecological efficiency with data envelopment analysis (DEA). European Journal of Operational Research. 132(2), 312-325.

Elkington, J., 1994. Towards the sustainable corporation: Win-win-win business strategies for sustainable development. California Management Review. 36(2), 90-100.

EPE. National Energy Balance Rio de Janeiro, 2014. The Electronic Farmer https://ben.epe.gov.br/downloads/S%C3%ADntese%20do%20Relat%C3%B3rio%20Final_2014_Web.pdf last accessed June 2014.

Ferreira, C.M.C., Gomes, A.P. (Eds.), 2009. Introdução à análise envoltória de dados: teoria, modelos e aplicações. Editora UFV, Minas Gerais.

Flórez-Orrego, D., Silva, J.A.M., Oliveira Jr., S., 2014. Renewable and non-renewable exergy cost and specific CO2 emission of electricity generation: The Brazilian case. Energy Conversion and Management. 85, 619–629.

Gerdessen, J.C., Pascucci, S., 2013. Data Envelopment Analysis of sustainability indicators of European agricultural systems at regional level. Agricultural Systems. 118(0), 78-90.

GRI, 2011. A new phase: the growth of sustainability reporting. GRI's Year in Review. The Electronic Farmer https://www.globalreporting.org/resourcelibrary/GRI-Year-In-Review-2010-2011.pdf last accessed November 2014.

GRI, 2012. Focal Point Brazil. The Electronic Farmer https://www.globalreporting.org/network/regional-networks/gri-focal-points/focal-point-brazil/Pages/default.aspx. last accessed January 2014.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L. (Eds.), 2009. Análise multivariada de dados. Bookman.

Hasna, A.M., 2010. Sustainability classifications in engineering: discipline and approach. International Journal of Sustainable Engineering. 3(4), 258-276.

IPCC, 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O. et al., (eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IISD (International Institute for Sustainable Development), 1992. Trade and sustainable development. Winnipeg, Manitoba.

Kajikawa, Y., 2008. Research core and framework of sustainability science. Sustainability Science. 3, 215–239.

Kharrazi, A., Rovenskaya, E., Fath, B.D., Yarime, M., Kraines, S., 2013. Quantifying the sustainability of economic resource networks: An ecological information-based approach. Ecological Economics. 90, 177-186.

La Rovere, E.L., Soares, J.B., Oliveira, L.B., Lauria, T., 2010. Sustainable expansion of electricity sector: Sustainability indicators as an instrument to support decision making. Renewable and Sustainable Energy Reviews. 14, 422–429.

Lélé, S.M., 1991. Sustainable development: A critical review. World Development. 19(6), 607-621.

Leszczynska, A., 2012. Towards shareholders' value: an analysis of sustainability reports. Industrial Management & Data Systems. 112(6), 911-928.

Lindsey, T.C., 2011. Sustainable principles: common values for achieving sustainability. Journal of Cleaner Production. 19, 561-565.

Liu, F., Ding, F.Y., Lall, V., 2000. Using data envelopment to compare suppliers for supplier selection and performance improvement. Supply Chain Management: An International Journal. 5(3), 143-150.

Lopez, M.V., Garcia, A., Rodriguez, L., 2007. Sustainable development and corporate performance: A study based on the Dow Jones Sustainability Index. Journal of Business Ethics. 75(3), 285-300.

Maxim, A., 2014. Sustainability assessment of electricity generation technologies using weighted multi-criteria decision analysis. Energy Policy. 65, 284–297.

Moldan, B., Janoušková, S., Hák, T., 2012. How to understand and measure environmental sustainability: Indicators and targets. Ecological Indicators. 17, 4-13.

Roca, L.C., Searcy, C., 2012. An analysis of indicators disclosed in corporate sustainability reports. Journal of Cleaner Production. 20, 103-118.

Sarkis, J., 1999. A methodological framework for evaluating environmentally conscious manufacturing programs. Computers & Industrial Engineering, 36, 793-810.

Sartori, S., Silva, F.L., Campos, L.M.S., 2014. Sustainability and sustainable development: a taxonomy in the field of literature. Ambiente & Sociedade. 17 (1), 1-20.

Searcy, C., Elkhawas, D., 2012. Corporate sustainability ratings: an investigation into how corporations use the Dow Jones Sustainability Index. Journal of Cleaner Production. 35(0), 79-92.

Searcy, C., 2009. Setting a course in corporate sustainability performance measurement. Measuring Business Excellence. 13(3), 49-57.

Singh, R.K., Murty, H.R., Gupta, S.K., 2007. An approach to develop Sustainability Management Systems in the steel industry. World Review of Entrepreneurship, Management and Sustainable Development. 3, 90-108.

Staniškis, J.K., Arbačiauskas, V., 2009. Sustainability Performance Indicators for Industrial Enterprise Management. Environmental Research, Engineering and Management. 2(48), 42-50.

Wang, T.F., Song, D.W., Cullinane, K., 2002. The applicability of data envelopment analysis to efficiency measurement of container ports. In: Proceedings of the international association of maritime economists conference. 13-15.

Wong, W.P., Wong, K.Y., 2008. A review on benchmarking of supply chain performance measures. Benchmarking: An International Journal, 15(1), 25-51.

Wu, J., Wu, T., 2012. Sustainability indicators and indices. In: Madu and Kuei (eds). Handbook of Sustainability Management. Imperial College Press, London.

Appendix A - CRS and VRS model: performance benchmarks

DMU	CRS	Benchmark (λ)	VRS	Benchmark (λ)
A	1	A(1)	1	A(1)
B	1	B(1)	1	B(1)
C	1	C(1)	1	C(1)
D	0.0029	B(0.00027); C(0.00009); L(0.032); M(0.0020); N(0.0022)	0.0464	K(0.31); L(0.64); N(0.05); R(0.0013); T(0.0012)
E	0.0317	A(0.0002); B(0.019); L(0.01); R(0.0016)	0.3294	H(0.08); K(0.52); L(0.0021); N(0.24); R(0.06); T(0.11)
F	0.0528	A(0.0041); B(0.015); L(0.016); M(0.011)	0.3943	L(0.19); M(0.009); N(0.23); T(0.58)
G	0.6066	K(0.64); L(0.53); M(0.12)	0.7363	K(0.75); L(0.064); M(0.19)
H	0.5572	A(0.0022); C(0.013); L(0.014); M(0.0050); N(0.12)	1	H(1)
I	0.0206	A(0.000006); L(0.014); O(0.005)	0.6354	L(0.36); N(0.13); T(0.52)
J	0.0142	A(0.00006); L(0.009); M(0.0002)	0.5272	L(0.29); N(0.38); T(0.34)
K	1	K(1)	1	K(1)
L	1	L(1)	1	L(1)
M	1	M(1)	1	M(1)
N	1	N(1)	1	N(1)
O	1	O(1)	1	O(1)
P	0.0186	L(0.0041); M(0.003); N(0.00016); Q(0.00075)	0.1789	A(0.00014); L(0.78); N(0.22); R(0.00051); T(0.014)
Q	1	Q(1)	1	Q(1)
R	1	R(1)	1	R(1)
S	0.0338	L(0.007); M(0.001); N(0.0025); Q(0.000009)	0.5822	B(0.0010); K(0.09); L(0.00004); N(0.89); T(0.019)
T	1	T(1)	1	T(1)
U	0.009	L(0.018); O(0.000031)	0.2905	K(0.55); L(0.32); N(0.14); T(0.04)
V	0.4597	L(0.0082); M(0.053); N(0.018); Q(0.068)	0.4687	L(0.87); M(0.051); N(0.020); Q(0.07)
W	0.5735	A(0.0015); L(0.0026)	1	W(1)
Z	0.0136	A(0.0011); B(0.00015); L(0.043); M(0.0040)	0.1217	K(0.37); L(0.25); T(0.38)