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Marie Pavláková Dočekalová, Alena Kocmanová, Jana Hornungová

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Marie Pavláková Dočekalová[1], Alena Kocmanová[1] and Jana Hornungová[1]

[1]University of Technology, Faculty of Business and Management, Brno, Czech Republic
{docekalova, kocmanova, hornungova@fbm.vutbr.cz}

Abstract. Corporate environmental performance is discussed in this paper. The aim of the paper is to propose a framework for an environmental performance benchmarking model. Corporate environmental performance is measured by key performance indicators (KPIs): Emissions of Greenhouse Gases, Water Consumption, Waste Production and Gross Value Added. Performance is benchmarked against the production frontier estimated by Data Envelopment Analysis. The environmental performance benchmarking model was created and tested on real corporate data. The model determines relative corporate environmental performance, identifies weaknesses in performance and quantifies performance gaps.

Keywords: corporate environmental performance · benchmarking · data envelopment analysis.

1   Introduction

Reporting corporate environmental performance is now commonplace among large enterprises. Twenty years ago, it was performed by just a few pioneers, and in the Czech Republic, for example, it can be said with little exaggeration that no companies informed their stakeholders about their environmental performance. In April 2014, the European Parliament adopted a directive that introduces the obligation that companies with more than 500 employees report on their social responsibility and, therefore, the impact of their business activities on the environment. Corporate environmental performance directly affects many corporate stakeholders – employees, consumers, the community, government bodies, etc. These stakeholders create a demand for clear and relevant information to support their decision-making. Traditional performance evaluation systems do not reflect the requirements of corporate stakeholders. The aim of this paper is to integrate the measuring of corporate environmental performance into performance measurement systems by proposing a framework for an environmental performance benchmarking model.

2 A Theoretical Approach to Environmental Performance

Corporate environmental performance is defined as the impact of the company on the environment. A company's influence on the environment is assessed in terms of harmful activities affecting the environment [1]. ISO 14031 defines environmental performance evaluation as a "process to facilitate management decisions regarding an organization's environmental performance by selecting indicators, collecting and analyzing data, assessing information about environmental performance, reporting and communicating, and periodically reviewing and improving this process" [2].

There has been a great debate about the relationship between corporate environmental performance and economic performance. Both positive and negative statements can be found in scientific publications. The authors in [3] concluded that environmental and economic corporate performance are positively linked and that industry growth moderates the relationship, with the returns in environmental performance being higher in high-growth industries. The authors in [4, 5, 6] state that economic benefits are attained by the use of brands and advertisements providing information about the sustainability of products, thereby supporting product differentiation. On the other hand, a meta-analysis focusing on 37 empirical studies examining the relationship between environmental and economic performance shows that the results remain ambiguous despite three decades of theoretical and empirical research [7].

2.1 Environmental Benchmarking

Benchmarking represents a way of finding quality and achieving success on the basis of organic growth. The approach taken by companies to environmental benchmarking is influenced by the regulatory context, company strategy, product type, corporate and national culture, resource costs and stakeholder demands [8]. According to [8], environmental benchmarking can be split into four categories: regulatory, gross emissions, efficiency and life cycle.

The principle of benchmarking is included in the ISO 14000 standards relating to environmental management. The process of implementing environmental benchmarking based on the ISO 14001 EMS standard is described in, for example, [9]. Corporate environmental performance is benchmarked against:

- the organization's environmental policy,
- environmental objectives,
- environmental targets, or
- other environmental performance requirements [10].

The Best Available Techniques (BAT) can also be used as a benchmark for environmental benchmarking [11]. At the EU level, BAT for selected industrial and agricultural activities are defined and quantified in Best Available Techniques Reference Documents (BREF).

The use of the following factors is an extremely common approach in setting benchmarks:

- the average value in an industry,
- the best-performing company in an industry,
- the value of the previous period.

Performance can also be measured against the production frontier. Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are methods that can be used for the purposes of estimating the production frontier. SFA has been defined by the authors [12, 13]. SFA is based on the estimation of a stochastic frontier production function by econometric methods. DEA has been defined by the authors [14] and is based on the estimation of a production function by techniques of linear programming. The DEA method was used for performance evaluation and benchmarking by, for example, [15, 16].

3   Methodology

An environmental performance benchmarking model was created and tested on real corporate data. The given data was taken from large Czech manufacturing companies for the year 2012. This industry was chosen because manufacturing companies exert a significant impact on the environment. The sample is described in Table 1.

Criterion	*N*	*%*
Number of employees		
250-500	10	55.5
501-1000	3	16.7
1001-2000	2	11.1
above 2000	3	16.7
Sector (as consistent with CZ-NACE)		
20. Manufacture of chemicals and chemical products	3	16.7
24. Manufacture of basic metals	3	16.7
25. Manufacture of fabricated metal products	7	38.9
27. Manufacture of electrical equipment	2	11.1
28. Manufacture of machinery and equipment n.e.c.	3	16.7
Legal form		
Joint-stock company	11	61.1
Limited company	7	38.9

Table 1. Research sample(N – number of companies, % - percentage in the sample)

The first step in creating a corporate performance measurement system is identifying relevant key performance indicators (KPIs). Environmental KPIs are often non-financial metrics. Mathematical and statistical methods were used to determine the environmental performance indicators. For a detailed description of the construction of environmental KPIs see [17, 18, 19].

Originally, the set of environmental KPIs consisted of seven variables: *Environmental Non-investment Costs, Air Emissions, Emissions of Greenhouse Gases, Energy Consumption, Water Consumption, Waste Production* and *Hazardous Waste Production*.

The first step in data processing was a quality check carried out in order to find out whether there were any erroneous or missing data. The following statistic measures were computed in order to obtain a basic knowledge of performance indicators: mean, range, standard deviation and variance. A correlation analysis was performed in order to understand the relationship between the variables. High values of pair correlation coefficients, i.e. |r| > 0.8, suggest multicollinearity. The variance inflation factor (VIF) was also used to detect multicollinearity. The VIF can be detected from an inversion matrix of the correlation matrix. Redundant KPIs were removed from the model. The reduced set of environmental KPIs then contained: *Emissions of Greenhouse Gases, Water Consumption* and *Waste Production*.

In this paper corporate performance is benchmarked against the production frontier – efficient frontier, which is constructed by efficient companies. The production frontier is estimated by Data Envelopment Analysis (DEA). The DEA method potential consists of identifying the best practice in the industry. The DEA model is based on assessing the quantity of consumed inputs by the produced outputs and estimation of the production possibility frontier. Three environmental KPIs (*Emissions of Greenhouse Gases, Water Consumption* and *Waste Production*) are considered as inputs. The goal of every business is to minimize values of these KPIs. *Gross Value Added* (GVA) is considered an output. GVA is the difference between the total production of goods and services and consumption (the value of goods and services consumed in production) – this approach is taken from the Eco Management and Audit Scheme (EMAS III). An input-oriented model with constant returns to scale (CCR model) is computed. The mathematical background of the model is described in [14].

The mathematical model of the primary input-oriented CCR model:

$$\max z = \sum_{i}^{r} u_i y_{iq},$$ (1)

$$\text{on conditions: } \sum_{i}^{r} u_i y_{iq} \le \sum_{j}^{m} v_j x_{jk}, \ \sum_{j}^{m} v_j x_{jq} = 1, \ u_i \ge \varepsilon, v_j \ge \varepsilon .$$ (2)

Where z is the coefficient of the technical efficiency of a company C_q. u_i and v_j are individual weights assigned so as to maximize efficiency and ε is an infinitesimal constant that ensures that all weights of inputs and outputs are positive.

The professional optimization program Frontier Analyst from the company Banxia Software, which is very user friendly, was used for the model. The simplest method from the viewpoint of demands on software is the computation of DEA models with the use of MS Excel or using programmed applications such as DEA-Excel by Professor Jablonský and DEA Excel Solver by Professor Zhu. The specialized optimization software Lingo developed by the company Lindo Systems uses a special modelling language for notation. The model can also be imported into the program in MPS for-

mat. MPL for Windows from the company Maximal Software is an open optimization system.

4 Results and Discussion

Figure 1 shows an environmental performance measurement system based on a benchmarking model. An environmental performance measurement system must be part of a corporate performance measurement system. In order to provide the whole picture about corporate performance, the corporate performance measurement system must also consider the social dimension in addition to the environmental and economic dimension. A balance between these three factors of corporate performance creates a triple-bottom-line and brings sustainability to organizations [20, 21, 22].
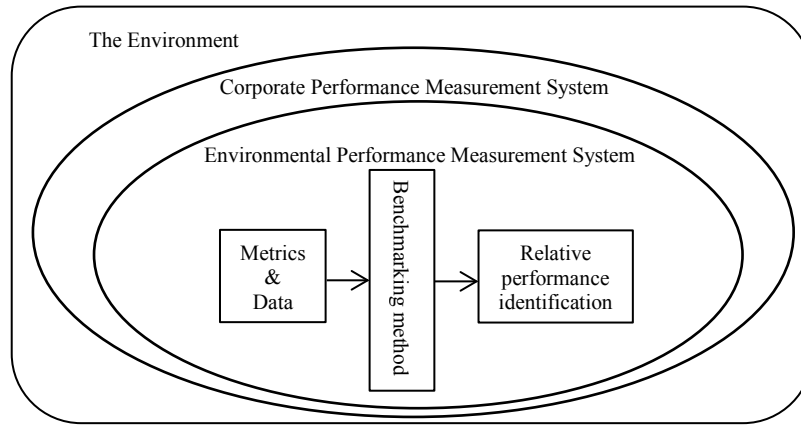

Fig. 1. Environmental performance measurement system

Metrics (environmental KPIs) and their values (data) are entered into the environmental performance benchmarking model. The outputs of the model are identification of:

- relative corporate performance and benchmarks,
- the best practice in the group of analyzed companies.

Table 2 presents the relative performance of all companies in the group given by the coefficient of technical efficiency derived from the DEA model. Performance is relative because it expresses the efficiency of the company within the studied group of companies. If it is equal to 100 %, this means that there is no company in the group that has a better performance. If the value is less than 100 %, there is at least one other company which is more effective. Both absolute and relative potential improvements are part of the output of the DEA model calculations. Table 2 gives relative potential improvements. The best-performing companies are "A", "G" and "Q". These efficient companies are referred to as "peer companies" and determine the efficiency

frontier, i.e. they use the minimum quantity of inputs to produce the same quantity of outputs.

Company	Relative performance (%)	Potential improvement (%)		
		Emissions of Greenhouse Gases	Water Consumption	Waste Production
A	100.00	0.0	0.0	0.0
B	27.16	-99.9	-72.8	-83.0
C	3.9	-96.9	-99.7	-96.9
D	1.41	-98.6	-100.0	-98.6
E	1.00	-99.0	-99.7	-99.0
F	2.00	-98.0	-99.1	-99.5
G	100.00	0.0	0.0	0.0
H	**69.36**	**-30.6**	**-54.5**	**-30.6**
I	30.71	-69.3	-85.0	-69.3
J	11.88	-89.0	-88.1	-88.1
K	10.56	-100.0	-89.4	-97.3
L	90.43	-9.6	-67.2	-9.6
M	4.78	-100.0	-95.2	-98.7
N	7.28	-100.0	-92.7	-96.7
O	7.53	-100.0	-92.5	-92.5
P	50.54	-49.5	-87.4	-49.5
Q	100.00	0.0	0.0	0.0
R	30.12	-69.9	-97.7	-69.9

Table 2. Corporate Performance – results of the environmental performance benchmarking model

Let us analyze the performance of company "H" further. This company is not effective from the viewpoint of environmental KPIs per Gross Value Added. Table 3 gives the benchmarks for the environmental KPIs that will make sure that the company "H" becomes effective at the current level of Gross Value Added which is 378,433 thousand CZK.

KPIs	Emissions of Greenhouse Gases (t)	Water Consumption (m³)	Waste Production (t)
Actual performance	0.01	4116.00	308.57
Benchmark	0.01	1873.07	214.04

Table 3. Environmental performance of company "H"

Individual environmental KPIs together with their benchmarks can be visually integrated in an AMOEBA graph. In Figure 2, the benchmark is considered 100 % and the actual performance of company "H" is relative to the benchmark. Users can see at a glance that Water Consumption significantly exceeds its benchmark and is therefore the weakest point in the environmental performance of this particular company.
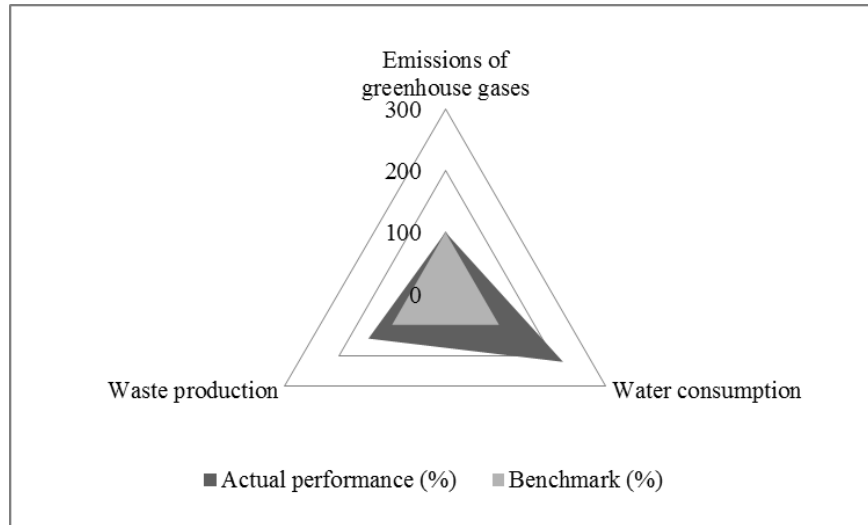

Fig. 2. Environmental performance of company "H"

The graphic presentation of environmental KPIs in the context of their benchmarks makes the model outputs clear and easy to understand because it is obvious at a glance which KPIs effect environmental performance positively and negatively. The model outputs allow users to identify weaknesses in performance and to quantify performance gaps, for which reason the environmental performance benchmarking model can serve its users as a basis for decision-making and performance management. Information about environmental performance should be an integral part of corporate reporting [23, 24].

5   Conclusions

A framework for an environmental performance benchmarking model was proposed in this paper. Data Envelopment Analysis is the benchmarking method used in the model. This approach has the following advantages: the performance of the company is expressed in one number given by the coefficient of technical efficiency, the model quantifies necessary improvements – performance gaps and also identifies the "best practice" in the particular industry. Information then becomes an important source material for quality decisions by the management. The weakness of the model is that

performance is relative, and adding another company to the analyzed group will change the environmental performance.

Acknowledgements

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