The Relationship between Critical Realism and Performance Measurement through Data Envelopment Analysis

Kazim Baris Atici
Hacettepe University
Department of Business Administration
06800, Beytepe, Ankara
Turkey

Abstract

This paper investigates the philosophy of science stream behind Data Envelopment Analysis (DEA) modelling, which is widely used for performance assessment of organizational units and presents a discussion of how Critical Realism (CR) philosophy introduced by Roy Bhaskar can be associated with the DEA methodology. As well as being an Operations Research (OR) tool, which is asserted to hold a critical relativist position, it is possible to directly associate Data Envelopment Analysis with Critical Realism. This paper discusses the realist and relativist aspects of Data Envelopment Analysis after discussing the main concepts of CR and its relation with OR.

JEL Codes: A12, N01, C44

Keywords: Critical Realism, Data Envelopment Analysis, Philosophy of Science, Performance Measurement

1. Introduction

Critical Realism (CR) approach, which is mainly associated with Roy Bhaskar, is a philosophical approach holding an ontologically realist and epistemologically relativist position within the philosophy of science. Mingers (2000) advocates that this approach can be an underpinning philosophy for Operations Research (OR) (*a.k.a Operational Research*) discipline whether it is seen as a natural or social science. Within OR, Data Envelopment Analysis (DEA) is a performance measurement method, which makes use of linear programming approach to assess how organizational units or organizations themselves perform relative to other. It has been used in performance evaluations both in public and private sectors all over the world (see Liu et al., 2013).

Current paper aims to provide insight about the position of Data Envelopment Analysis methodology within the philosophy of science. Specifically, it proposes that as the OR discipline, one of its widespread used methods; Data Envelopment Analysis can also be closely associated with the critical realism philosophy. To advocate that DEA is associated with CR philosophy is not very unexpected, since it is an OR technique and there is already an ongoing assertion that OR is a critical relativist discipline (Mingers, 2000; Ormerod, 2002). The paper first time discusses specifically how the concepts of CR can be fitting with the DEA methodology. The discussion is shaped around four main dimensions: the **transitive role** of DEA modelling from past to future, discussion of how DEA holds a **realist** position, explanation of the importance of **relativity** within DEA methodology and argumentation of how **domains of science** defined by Bhaskar (1975) are related with the DEA concepts.

The paper is organized as follows: Section 2 presents the fundamentals of Roy Bhaskar's critical realism philosophy. Section 3 provides a brief discussion of the relationship between Critical Realism and Operations Research. Section 4 discusses how Critical Realism is associated with Data Envelopment Analysis methodology in four subsections. Finally, Section 5 concludes.

2. Critical Realism

In the Philosophy of Science, Critical Realism (CR) is an approach generally associated with British philosopher Roy Bhaskar. In his inspiring work "A Realist Theory of Science", Bhaskar presented the foundations of Critical Realism. Bhaskar's primary aim in this book was "to provide a systematic realist account of science" as an alternative to positivism (Bhaskar, 1975:12).

In analysing the philosophy behind the Critical Realism and Roy Bhaskar's views, we have to mention the concepts of transitive vs. intransitive objects of knowledge, the analyses of perception & experimental activity, and the domains of real, actual &empirical.

2.1. Transitive vs. Intransitive Objects of Knowledge

Bhaskar mentions and distinguishes between two sides of knowledge in the philosophy of science. One side is intransitive objects of knowledge. Bhaskar (1975:22) defines intransitive objects of knowledge as: "The real things and structures, mechanisms and processes, events and possibilities of the world and for the most part they are quite independent of us".

These objects of knowledge do not need human existence to exist. The earth would spin around the Sun, the gravity would exist or as in the Bhaskar's example, "the metals would conduct the electricity in the way they do" (1975:22), without any scientist produce knowledge about them.

The second side of knowledge is the transitive objects of knowledge. According to Bhaskar (1975:21), transitive objects of knowledge include: "The antecedently established facts and theories, paradigms and models, methods and techniques of inquiry available to a particular scientific school or worker".

These objects of knowledge represent the social character of science producing knowledge through inheritance of prior developments. Bhaskar (1975) claims that it is impossible to imagine a science without scientific or pre-scientific antecedents.

2.2. The Analyses of Perception and Experimental Activity

According to Bhaskar (1975), a scientifically significant experience depends on both sense-perception (the role of men as perceivers) and experimental activity (the role of men as causal agents). Bhaskar (1975) considers these two independently and performs a transcendental analysis of experience in two dimensions.

The first dimension of analysis of experience is the analysis of perception. In the analysis of perception, Bhaskar (1975) distinguishes between events and experiences and he advocates that a world of events exists without any experiences. This proposition, in a manner, attributes to the intransitive objects of knowledge. Things are happening in the nature independent of human beings perceive them or not. However, in the occurrence of a scientifically significant experience, there is a role of men as a perceiver.

During the analysis of perception, Bhaskar (1975) also underscores the unperceived or unperceivable events. He states that even though an event is unperceived or unperceivable by men, it does not necessarily mean that there is no possibility for that event to occur. There are many events occurred in the history of science that were not imagined by men at some point in time but eventually provided knowledge. He also advocates that the possibilities of perception are continuously increasing because of the transitive process of science (Bhaskar, 1975:32).

As a second dimension in analysing experience, Bhaskar analyses experimental activity. In the analysis of experimental activity, Bhaskar (1975:33) advocates that "In an experiment we are a causal agent of the sequence of events, but not of the causal law which the sequence of events, because it has been produced under experimental conditions, enables us to identify (…) For, to repeat, in an experiment, we produce a pattern of events to identify a causal law, but we do not produce the causal law identified"

By indicating this point, Bhaskar defines an ontological distinction between causal laws and sequences of events. Also, he claims that an experimental activity can only be satisfactory if the causal law identified is valid outside the contexts in which the sequence of events generated. In addition, the causal laws of our nature would exist even the planet was destroyed or a scientist fails in a result of experiment. As a result for his analysis of experimental activity, he concludes that "constant conjunction of events is no more necessary nor sufficient condition for a causal law" (Bhaskar, 1975:33).

From concepts discussed about the Bhaskar's views, we can suggest that Bhaskar (and so the Critical Realism approach) hold an ontologically realist and epistemologically relativist position. Ideas of transitive nature of science as a social process and sense-perception with the role of men as perceivers in science are the evidences of this epistemologically relativist position. Intransitive objects of knowledge, independence of events from experiences, ideas about unperceived or unperceivable events, universality of causal laws and ontological distinction between causal laws and events are all reflections of an ontologically realist point of view.

2.3. Domains of Actual, Real and Empirical

As mentioned above, Bhaskar (1975) distinguishes between events and experiences. He states that "events occur independently of experiences" (1975:13). He also advocates that "real structures exist independently of and are often out of phase with the actual patterns of events". In other words, he defines stratification between structures (i.e. mechanisms), the events that they generate and events that are actually experienced (Mingers, 2000). On the basis on this stratification, Bhaskar (1975) defines three distinct domains in the world of research; empirical, actual and real. Mingers (2000:1261) explain these domains as: "The real contains mechanisms, events, and experiences, i.e. the whole of reality; the actual consists of events that do (or do not) occur and empirical includes, those events that are observed or experienced".

In other words, the domain of actual that includes the events and experiences is the domain of "What has happened?", the domain of empirical that include only experiences is the domain of "What do you perceive?" and finally, the domain of real including events, experiences and mechanisms is the domain of "What caused the happening?".

3. Critical Realism and Operations Research

Before discussing the relationship between the Critical Realism philosophy and Data Envelopment Analysis, it is worth mentioning that there is already an existing discussion in the literature about CR being an underpinning philosophy of Operations Research. Operations Research (OR) – which is also referred as Management Science (MS) – is defined by Winston (2003:1) as "A scientific approach to decision making that seeks to best design and operate a system, usually under conditions requiring the allocation of scarce resources". Although some models and techniques of it started earlier, the OR discipline is accepted to start during World War II. After war, most of the scientists working on this area switched to apply OR methodology to solve management problems in various industries. After the introduction of computers in early 1950s, OR experienced a rapid growth (Ravindran, 2008). Since then, it became an important discipline and various models, methods, algorithms and interdisciplinary applications are developed in this area. Data Envelopment Analysis is one of those methods which is used for performance measurement in organizational units.

In the OR literature, an important study discussing the relationship between OR and Critical Realism (CR) is the study by Mingers (2000). In this study, Mingers claims and discusses that CR can be an underpinning philosophy for OR. As a starting point, he brings up the debates about the nature of OR such that whether OR is a science or technology, if it is a science (at least it is related to science), whether it is a natural science or a social science and what is the appropriate philosophy of science for OR whether it is a natural or social science? (Mingers, 2000:1256). He discusses the OR and CR relationship from different perspectives of natural or social science. He mentions that although OR dominantly seen as a natural science, since it is conducted in social organizations, social science can also be relevant (Mingers, 2000:1259).

Rather than discussing the nature of OR as a natural or a social science, I would like to focus on Mingers' views about CR can be a suitable philosophy for OR. Mingers provides three main arguments about CR being appropriate philosophy for OR. Firstly, CR enable OR people to hold a realist standpoint which he believes that a majority of OR colleagues hold. Secondly, CR takes both natural and social sciences into account and covers various approaches inside the OR discipline. As a final argument, he claims that CR fits well with the application oriented nature of OR (Mingers, 2000:1263).

On the other hand, the ideas advocated in Mingers (2000) are discussed by Ormerod (2002) in a later paper. Ormerod argues that when looking at the philosophy for OR, the debate can be conducted in three levels. In the first level, the debate about the nature of OR (whether it is science, technology or social science etc.) takes place. In the second level, an overarching philosophy (defined as: "the set of beliefs that will be used to conduct our affairs") is needed. As a third and a final level, the underpinning philosophy comes as "deeper arguments about the nature of world, people and activity" (Ormerod, 2002:351). He believes that debates in the first and second level will shape the underpinning philosophy and enable it adapt and change. According to Ormerod (2002), before searching for an underpinning philosophy, an overarching philosophy taking the debates about the nature of OR into account should be taking place.

Consequently, there are some beliefs in the OR literature that CR can make a contribution and provide insight to OR researchers as a philosophy.

Although we cannot strictly claim that CR is the philosophical approach behind the OR, it is clear that some relation between them can be established. Data Envelopment Analysis (as an OR tool) holds some properties that can be associated with Critical Realism, which are discussed in the following section.

4. Critical Realism and Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a non-parametric performance measurement approach for identifying relative efficiency of Decision Making Units (DMUs) producing multiple outputs using multiple inputs. DEA relies on constructing a multidimensional production technology where each dimension represents an input or an output. The efficiency of a unit is then measured relative to an efficient frontier representing the best performers in the given technology. The method makes use of linear programming and does not require establishment of functional relationships between inputs and outputs. For each unit in a data set, a separate linear programming model is established and solved in order to investigate if there is a possibility for a unit to improve its performance. If there is no potential improvement for a unit (which means that it is performing efficiently relative to others), the linear programming model results in assigning an efficiency score of 100% to that particular unit. Unit or units with 100% efficiency defines the efficient frontier. Efficiency score of a unit is calculated as the distance to the efficient frontier. The reader may refer to Cooper et al. (2006) for mathematical modelling of DEA.

DEA has rooted from the study of Farrell (1957) and presented to the Operations Research literature by the study of Charnes et al. (1978). Since then, DEA models have been widely applied for the real world organizations in different industries, including public and private sectors all over the world. Generally, a Decision Making Unit (DMU) in DEA is regarded as the entity responsible for converting inputs into outputs and whose performances are to be evaluated. In managerial applications, DMUs may include various private and public sector entities such as banks, department stores, supermarkets, hospitals, schools, public libraries and so forth (Cooper et al., 2006).As well as being a diagnostic tool for answering the question of which units are better in a given production technology, it also serves as an exploratory tool where the factors causing efficiency and inefficiency can be identified. This is done by observing the optimal weights attached to input and output factors as a result of solving the linear programming model designed for the units. The results reveal the input and output factors affecting the efficiency and inefficiency, in other words, strength and weaknesses of the evaluated unit. Furthermore, the efficiency scores obtained has been widely used for an ex-post analysis (mostly via regression), which aims to explore the factors underneath the inefficiencies.

4.1. Transitive Nature of DEA Modelling

In William Cooper's (one of the three authors of the 1978 paper) final paper summarising the origins and the development of the technique (2014), it can clearly be observed the technique has evolved via transitive nature of the knowledge on DEA modelling. Beginning from Farrell's seminal paper the relative efficiency measurement research is vastly evolved through inheritance of prior developments. DEA has an antecedent relationship with traditional ratio-based performance evaluation approaches and mathematical programming. Simply, in the root of DEA there is the approach of output/input ratio. The model is deriving from this ratio based model and is an adapted version of ratio model into an optimization model that enables to perform the performance measurement of a unit relative to others. With step-by step increments over previous developments, the application scheme and areas of the technique grew enormously. A recent literature review (Liu et al., 2013) indicates this great expansion. The 20 influential academic journals in the field published over 1,700 academic papers on DEA since the first paper published in 1978 over 1,000 of them are after 2000. Also, the multi-disciplinary application frame of the technique contributes to transition of knowledge between different disciplines such as Operations Research, economics, political science or engineering. Cooper (2014) points even more research directions for future DEA researchers such as organizational behaviour and behavioural economics, which will pursue DEA's role in knowledge transition. Contributing to the transition of knowledge can be attributed to nearly all Operations Research methodologies, yet to Operations Research as a whole. The main discussion that can associate CR and DEA can be put around their **ontological** and **epistemological** position.

4.2. Ontological Realism of DEA Modelling

It is possible to discuss the realistic position of DEA modelling over four aspects that come into existence on fundamental assumptions of the technique: multidimensionality, feasibility of observed data, free disposability and causality.

Zhu (2002) states that "*a business unit's performance is a complex phenomenon requiring more than a single criterion to characterize it*". Multidimensionality in DEA modelling is important in handling the complexity of the business environment that a unit operates in. Instead of interpreting a single ratio while leaving all the other factors out, DEA enables us to evaluate a business unit in a multidimensional space where all possible combinations of units are defined as a production possibility set. This **multidimensionality** allowing the incorporation of multiple factors enables us to provide a broader view on an organizational unit's performance and identify what really happens in the unit.

Of course, selecting the factors in the analysis is problem specific and requires a cautious handling. Although no functional relationship that mat reflect causality between inputs and outputs is required to be established in DEA technologies (unlike the parametric techniques), we can still mention that causal mechanisms are addressed. One of the main considerations in DEA in selecting the input and output variables is that the analysis should be comprehensive so that no activity is left out if resources (i.e. inputs) are allocated on them. In other words, all outputs selected are related to the all inputs identified with causal mechanisms. Given that, DEA modelling design, in a way, acquires **causality**.

One of the main axioms of the DEA technique is the **feasibility of the observed data** (Banker et al., 1984). The production possibility set is constructed by enveloping the observed data and applying the principle of **free disposability** which translates as: it is always possible to be inefficient. For example, if an organisational unit produces 2 units of output with 1 unit of input, then it is always possible to produce 1 unit of output with 1 unit of input (i.e. it is always possible to produce less with the same input) or it is always possible to produce 2 units of output with 2 units of input (i.e. it is always possible to consume more to produce the same). Therefore, a production possibility set or a technology consists of observed units and theoretical units which are realistically possible to attain. DEA then becomes series of experimental activities performed for each unit investigating at which part of the technology the given unit is located. It is a search for if it possible to perform better for a certain unit.

4.3. Epistemological Relativism of DEA Modelling

Relativism is also significant in the nature of DEA modelling. Productivity in a very general sense can be measured through the ratio of outputs to inputs. A business unit would like to achieve more outputs with use of fewer inputs. Therefore, units attaining the level of greater than 1 in terms of this ratio can be considered as productive. However a unit's ratio itself may not tell much about its performance without any comparison to other units performing the same operations. Since every organization is an open system, it is not possible to define a contemporary performance measure with no attention at the competitors or similar organizations performing the similar operations. DEA modelling, as mentioned earlier, takes into account the relative position of the units evaluated to an efficient frontier. The frontier consists of the best performers in the data set. An efficiency score obtained for a unit is a relative measure of its improvement factor which takes best performers in the given production possibility set into account. It is clear that the whole DEA idea is based upon relative position of an evaluated unit's performance. In DEA modelling, a business unit's performance is dependent on not only its own output-input ratio but also it relative position among other units performing similar operations. Therefore, this strong relative approach can be an evidence that DEA holds an epistemologically relativist position in terms of philosophy of science.

4.4. DEA and Domains of Actual, Real &Empirical

Bhaskar's definitions of three main domains of science can easily be associated with several aspects of DEA modelling, which are summarized in Table 1. The domain of **actual**, which is represented by the question of **"What has happened?"** can correspond to the ratio of outputs to inputs for a unit. The ratio indicates the actual performance of the evaluated unit. In the **empirical** domain, the question is **"What do you perceive?"** The perceived performance can be the relative position of a unit's output/input ratio among other units. An actual performance is realized and empirical analysis investigates the perceived position of this actual performance among others. Finally, the domain of **real**, where the question of **"What caused happening?"** holds a place in DEA modelling through observing the optimal weights attached to the input and output factors. Those weight values indicate what factors lie behind the efficiency or inefficiency of a unit, therefore point out the causes of being efficient or not.

Table 1: Association of DEA Concepts with Bhaskar's Domains of Science

Domain	Question	DEA Aspect
Actual	What has happened?	Output/Input ratio
Empirical	What do you perceive?	Relative position of the unit's performance
Real	What caused happening?	Optimal weights attached to inputs and outputs

5. Conclusion

Data Envelopment Analysis (DEA) is a widely used methodological tool to assess the relative performance of organizational units. A vast literature can be found on DEA applications measuring how efficiently organizational units perform in public and private sectors all around the world. This paper investigates the philosophy of science stream behind DEA modelling and presents a discussion of how Critical Realism (CR) philosophy introduced by Roy Bhaskar (1975) can be associated with the DEA methodology. As an Operations Research (OR) tool, it is already possible to assert that DEA modelling is critical realist since there is an established link between OR and CR and a discussion exists that CR is the underpinning philosophy of OR (Mingers, 2000; Ormerod, 2002).

This paper advocates that it is possible to specifically relate DEA to CR. Its **transitive nature** borrowing ideas and contributing to different fields as business studies, Operations research, economics and political science fits with Bhaskar's definitions of transitive objects of knowledge. Besides, it can be asserted that ontological realism and epistemological relativism position attributed to CR has some correspondence in DEA methodology. Realism of DEA stands upon the **multidimensionality** which enables the incorporation of all factors affecting a business unit's operations into modelling, **causality** relation between the input and output variables and the idea of **production possibility set** where all possible combinations of inputs and outputs are established relying on **feasibility of observed data** and **free disposability** principles. **Relativism** is the core of DEA modelling. The performance measurement with DEA relies on relative position of the evaluated units to an efficient frontier in a realist production possibility set. It is also possible to identify the factors behind the efficiency of evaluated units through DEA modelling. In conclusion, DEA methodology is interested in the **relative** position of the **actual** performance of a unit. The **empirical** model relies on the investigation of improvement factor of the unit within a constructed production technology and provides evidence for the cause for a unit to be efficient or inefficient. The method seeks to answer the three main questions: What has happened? What do you perceive? What caused happening? that can be associated with three main domains of science defined by CR (**actual**, **empirical** and **real**, respectively).

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