Theoretical discussion of the methods of the Production Possibility Curve and Life Cycle Assessment

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Abstract

This article aims to discuss the theoretical alignment between the Method of Production Possibility Curve and the Method of Life Cycle Assessment to identify key variables to measure and identify the environmental impacts throughout a product's life cycle.

Keywords: Method of Production Possibility Curve, method of Life Cycle Assessments, environmental factors.

Introduction

The environmental issue is widely discussed nowadays. There are acknowledgments about the forms of manufacturing can impact the nature, exploitation of resources, the processes of production or the distribution logistics. These steps do not act alone, and are interconnected both in operation and in the business model or strategy adopted. The attention for the environmental management offers optimization of the entire production system (Muting et al 2013) performance. Investigate the entire system, observing each stage, through an inventory of data and presentation of the generated effects on the environment, are functions of the method of Life Cycle Assessment (LCA). The LCA "Involves a holistic approach, bringing the environmental impacts into one consistent framework, whenever and wherever these impacts have occurred or will occur" (Lainez et al 2008). This concept is recognized as one of the most important tools for environmental assessment (Heijungs et al 2010). Environmental management is regarded as a key element of management for business (Tytec 1996) because it directs processes, people and stakeholders about environmental protection. In this sense, the sustainability of organizations depends on actions taken in the operations, services and other activities that address sustainability in a special way. Therefore, this measure has been exploited by active two key methodologies: monetary aggregation and physical indicators of sustainability (Singh et al 2011).
The form of monetary factors based on measurement can be performed by metric named environmental economic valuation methods. These methods are based on environmental economics that focuses ideas aimed at reducing interference on the environment. By focusing on this principle, the joints are focused on the balanced use of natural resources to fuel transformation processes or dynamics that occur along a supply chain. When this exercise occurs, the actions it intends to identify the value of the assets of nature that are not traditionally recognized. Basically, there is the use, exploitation, but there is no recognition (real) value of these. Despite naturalistic principles that inform environmental goods "does not have economic value", there is a need to value these elements not to ignorance of the importance of these exists, even economically represented. The question to be answered is to quantify these values, and what would be the variables of measurement.

**Main subject text**

Discuss the theoretical alignment between the Method of Production Possibility Curve and the Method of Life Cycle Assessment.

**Methodology**

This Article follows the premises of the proposed taxonomy for Vegara (2000) determined "as the means and as to the purposes" of a research. As for exploitation of research content: the research is exploratory review of the literature on methods of Environmental Economic Valuation and Life Cycle Assessment. Regarding about purposes: alignment method more adherent to the method of Life Cycle Assessment with presentation of the main environmental variables measuring environmental economic valuation.

**Literature review**

Methods of environmental economic valuation

The environmental economic valuation methods according to the line proposed by Hufschmidt et al (1983) and Bateman and Turner (1992) are avoided Cost Method, Travel Cost Method, Hedonic Pricing Method and Contingent Valuation Method. These methods amount prices obtained by real markets. These methods are the natural resources of economic valuation tools. Since valuation techniques may also be termed as indirect or revealed preference (methods of avoided costs, travel cost and hedonic pricing) and stated preference or direct (contingent valuation method). The values obtained by direct or revealed preference linked to observable behavior because it reveals the values. Moreover, values not observed or are considered not use indirect and may be represented by aesthetic or legacy data. Moreover, environmental issues involving valuation of different magnitudes, depending on the selected evaluation object. From another perspective, focused on the production function, the methods of environmental valuation price second real markets are determined by the methods of valuation of the benefits, according Hufschmidt et al (1983) and Bateman and Turner (1992): Method and dose-response method of replacement costs. In the following paragraphs, the methods will be detailed to understand their proper applications.

**Method of avoided costs**
This method measures expenditures devoted to processes or directed to the protection of human health endeavors. With this principle, their major applications are made to measure for preventive measures against exposure to toxic gases, air and noise pollution and processes aimed at improving drinking water (Pearce 1993).

Travel cost method

Basically, this method considers the expenses incurred in moving people from one place to another with the intention, in most cases, for entertainment (Nogueira et al 2000). This expenditure would serve as a parameter to measure the value of goods or services from the target location. Accordingly, the valuation would be related to consumer behavior in enjoying the good or service. Maybe that's why the accuracy of the method is affected by the difference in values assigned by people. The method has wide application in comparison interests of people before or after improvements made good or service of interest.

Hedonic pricing method

This method assesses the environmental values that may be associated with prices of private goods or services. Properties may have appreciation for environmental characteristic, for example, with around native reserves or water availability, which interfere with the function of the demand for these goods. The application of this method, according Tolmasquim et al (2000), is appropriate when there is relative environmental and property, and the marginal price of the environmental factor can be incorporated into realistic and marketing value.

Contingent valuation method

The method allows for the economic valuation of the environment second degree preferably people (Pearce 1993). The human position is related to the values of WTP (Willingness to Pay / WTP) and willingness to receive (Willingness to Accept / WTP). The WTP portrays a real environment in which people are interested in enjoying this. In hypothetical situations, willingness to pay is related to scenarios of environmental preferences desired by people.

Method dose-response

The dose-response method is framed in the production function. This technique measures the use of environmental resources as a supply for their contribution in the production of another good (Nogueira et al 2000). With this idea, the replacement of a product on the other, could, or should, minimize consumption of an environmental good, according to the principles of sustainability. Perhaps this recognition is related to the lack of economic value that would use such a feature, despite the existence of methods and techniques for this purpose. Thus, the natural resource directly affects the production function (Sinisgalli 2005). This instrument is also known as a method of producing function. The concept proposes an estimate of the marginal productivity related environmental variable. This assumption considers the environmental factor as an element that provides the dose (environmental as input) to the response (output) which determines the final product.
Method of replacement cost

This method is also linked to the production function to consider spending dedicated to restoring environmental systems that interference suffered by productive environments (Pearce 1993). Another way to measure these data by business need to be legislative or regulatory suitability for any particular organization of environmental regulation. This requirement would require regulatory compliance costs for this would be the representative value and replacement cost.

Method of production possibility curve

This method is a variant of the method of dose-response because it considers the production capacity as a result of the assets comprising the productive resources. In this sense, the inputs would be elements that determine the growth or reduction of production capacity, including natural resources. One way of measuring such economic resources, it would be possible through the production curve. The curve shows the behavior of the production before the interference from environmental factors. If losses or reductions to natural inputs, yield potential will be reduced. The factor of production, according to the neoclassical concept of Cobb-Douglas, may be associated with environmental factors (FA), capital (K), labor (T) and technology (S). Studies by Andzio-Bika and Wei (2005), Kamat and Tupe (2007) apud Prates and Bacha (2010), can be cited as examples of connection and relationship between environmental production function. The production potential is illustrated in Figure 1, which shows the curve related to the possibility of factors affecting the production yield.

![Figure 1: Cartesian representation of the production possibility curve.](image)

If, for example, the occurrence of reduced productivity (A to B), a condition of reduced environmental supply a greater extent than the variation factors of capital, labor and technology, could be expressed by the equation (1):

\[-\triangle FA > (+\triangle K + \triangle T) \times \triangle S\]
So, the reduction associated with decreased FA productivity could be measured by the change of capital and labor, in equation (2):

$$A - B = [(\triangle Q_x) \cdot P_x] + [(\triangle Q_y) \cdot P_y]$$

Variables: $\triangle Q_x$: variation the amount of product X.; $P_x$: price of product X; $\triangle Q_y$: variation in the quantity of a product Y; $P_y$: price of product Y.

In practical terms, the reduction in productivity will be valued currency unit in the difference between the product of capital (product price) and work (quantity produced). On the other hand, reducing the environmental factor could also be added that the smallest variation in capital, labor and technology shown in equation (3):

$$(-\triangle FA) < (+\Delta K + \Delta T) \times \Delta S$$

Mean productive operations have been optimized to such an extent to facilitate the work (W), and hence the capital (K), favoring the use of resources in nature. Perhaps, also by technological interference, through innovation, using renewable sources or alternatives to natural resource. That is, the research and development of alternative materials or replaced by others that are not natural sources, or synthetic nature, or by recycling could minimize the use of natural raw materials rather than the maximization of production (factors capital and labor).

**Technological potential and life cycle**

The factors of labor, capital and natural, as shown, interfere with the production factor. The active technology can also act on productivity and on the lifecycle of products. For example, by increasing or decreasing the life of a product, which, in turn, can affect the amount of emissions generated throughout its life cycle. A cycle of recapturing products, driven by reverse logistics, product recovery to return to the production process for reuse or recycling of components. In this regard, Figure 2 depicts at each of its quadrants tripartite relationship between the reuptake of product life cycle and the use of technology:

![Figure 2: Technology and the life cycle of products (OMETTO ET AL 2006)](image-url)
Therefore, the method of LCA is a powerful tool to measure, analyze and assist decisions to improve processes throughout the product life cycle, from "cradle to grave". With this idea, which Rosnay (1997) have argued about the need for "full reconfiguration of industrial processes, from regulating flows of energy, raw materials and products from the rational reuse of waste". We notice that this idea is in line with methods (Dose Response and Replacement Cost) that consider environmental valuation in the context of production and on the premise input-output. (Rebitzer 2004). A tool that helps identify and quantify the environmental impacts of products is the method of Life Cycle Analysis (LCA).

**Method of Life Cycle Analysis (LCA)**

LCA is a method of assessing the environmental impact of a product or process comprising steps ranging from the removal of the raw materials of nature entering the production system (cradle) to the provision of the final product after use (grave) (UNEP 2007). The method has international recognition since 1992 and was adopted by the International Organization for Standardization (ISO) and is part of the ISO 14000 environmental management dealing (ISO 1997). To highlight the use of this practice, the Finnish Environmental Institute conducted a research survey, "Use of Life Cycle Assessment (LCA) in global companies" (Nygren and Antikainen 2010) to identify the impact areas focused by the implementation of the method of LCA:

![Figure 4: Areas of impact identified by the LCA in global companies](image)

Besides these results were observed: difficulty in weighting of each of these impacts; methodological complexity of LCA for its implementation and the need to change the organizational positioning of LCA as a tool for organizational strategy process.
Discussion of the elements of algebraic formulas methods of Production Possibility Curve and Analysis Method of Life Cycle

Returning to the formulation method of calculating the curve production possibility, it is emphasized again that environmental factors are subject to variable capital, labor and technology, to a greater or lesser extent depending on the action of these elements.

\[ (-\Delta FA) > (+\Delta K + \Delta T) \times \Delta S \text{ or } (-\Delta FA) < (+\Delta K + \Delta T) \times \Delta S \]

The measurement on the inventory of natural resources for a product, to quantify the environmental allocation, can be determined by the method of Life Cycle Analysis for two formulations: sequential or matrix methods to calculate the mass balance of the processes resulting in a cycle of life. The sequential methodology determines the mass balance at each stage of the system, and their sum, evaluates the complete composition of the cycle in equation (4):

\[ BM = \sum Mi \cdot Ei \]

BM: mass balance, Mi: mass of input / process; Ei: energy consumed.

The method treats the matrix while each stage of the system, not separately evaluating each step, as is the sequential method. The array that consolidates the variables that encompass technological factors (technological matrix) and environmental (matrix operations) (HEIJUGS ET AL 1992). Figure 5 shows an example of array elements that consolidates the input / output of the economy (a), technological factors, and the elements of input / output to nature (b), environmental factors.

\[
\begin{pmatrix}
a_{11} & \ldots & a_{1i} & \ldots & a_{1n} \\
a_{21} & \ldots & a_{2i} & \ldots & a_{2n} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
b_{11} & \ldots & b_{1i} & \ldots & b_{1m} \\
b_{21} & \ldots & b_{2i} & \ldots & b_{2m} \\
\vdots & \vdots & \vdots & \vdots & \vdots 
\end{pmatrix}
\]

The mass balance calculation is made by the sum of the inputs / outputs, the process and the economic factor, shown in equation (6):

\[ BM = \sum Aij \cdot Pi \]

BM: mass balance; Aij: elements of input / output in line (i) e column (j) of the corresponding matrix; Pi: the intervention process.

The equation of mass balance, may consider any other type of asset that makes up the inventory of data involved. The inventory process, known as the inventory table is composed of the
coefficients (Ci) and process characteristics (Pi) for each environmental burden involved: \( B = \sum Ci \cdot Pi \)

The data are measured via array with application of Cramer's rule, which allows processes to be considered simultaneously, fundamental characteristic of this method. If we consider, for example, a manufacturing process which also involves production of recyclable material means there will be interference to the data matrices as follows: coefficients and different procedures for the introduction of recovered materials that have different production requirements of the standard process. Thus, the inventory would have a distinct variant of the original process: \( B' = \sum Ci \cdot Pi \)

This configuration (B') would be composed of the new coefficients (C) and processes (P) which would again recalculated by applying the matrix method. The transformation process operates concurrently with regular operations and alternative process (recycling), generate new valuation of inventory. The measurement of this result (with built-in process) allows to analyse which processes contributes most significantly on the environmental effects of the evaluated system. The purposely cited example serves to highlight a way to measure and evaluate the integration of processes with recyclable materials, this is not always the recovery of materials and incorporating recycling of components does not necessarily imply a reduction of environmental impacts. Such procedures sometimes require increasing complexities of operation or increased energy expenditure which means indirect environmental effects, not favoring sustainability issues. With this approach, it is observed that technological factors are assets that represent the function tautologically technology (T), which interfere with the conditions and labor productivity (T) and capital (K) involved, as well as the other fraction of the matrix, named array of interventions, which comprises the presence of environmental factors, in this sense, each factor alone or in combination may act on natural factors. Thus, the technological factor can also interfere on how the environmental assessment. Technology can increase the productive scale optimization of production systems or actions based on knowledge, more specifically, by learning, "Learning - by-doing" (Hillman 2008). The human experience and skills can produce or manufacture products or processes competitive factor for organizations with practices aimed for a "Cleaner Production" (Huppes and Ishikawa 2009; Numata Junior and Ugaya 2013) with "Eco-efficiency" (WBCSD 1996) with goal of reducing environmental impacts, and, if possible, induce demand (consumption) in the market, generating known as "rebound effect" (Murray 2011) effects. It should be emphasize that technological development is cumulative with "path-dependent" (Dosi 1992) generating an increasingly robust environment for organizations both for production and for environmental protection. Considering the technological factor as eyelinier in a consequential LCA approach the observed correlation in the change in the product life cycle (Ekvall and Tillman 1997) and in the form of intervention to be implemented processes for modeling purposes and expected results in scenarios designed (Weidema et al 2004; Sanden 2008; Höjer ET AL 2008). What stands out in this dimension of analysis, is the new role played by "emerging technologies" in favor of "adoption is more than relevant to the current environmental performance" (Hillman 2008). In fact, the concept of LCA principles houses that are adherent to the fundamentals of the Production Possibility Curve method to signal opportunities for organizational managers “proposals for strategic planning or replanning (design or capacity) of products or processes" (UNEP / SETAC 2009) to express a maximum production capacity in relation to the constraints of the natural resources and technological assets.
Final conclusions

In summary, it is observed that the variables, labor, capital and technology are common in the corollary of different formulas of measurement methods of exploitation of natural resources. These assets corroborate the neoclassical economic model to the dimensions most exploited today externality, environmental and regional factors. Environmental control practices were initiated within industrial premises, in consideration of the devices geared to labor and capital factors, which also expanded along the supply chain to the recognition of the importance of external factors on the production system. This idea, coupled with the identification of the elements of each measurement model, emphasizes that external factors can cause interference in nonlinear system analysis. This aspect offers research opportunities in the field of development of scenarios and modeling perspectives to offer in unfamiliar surroundings, so one can understand why this area being increasingly explored. Another front, more applied nature, interdisciplinary intervention is aligned with the use of technology to develop processes and strategies for environmental technological innovation.

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