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Green Productivity Index: Do Different Terms Measure The Same Things?

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ABSTRACT

Green productivity (GP) index is a measurement tool developed to analyze economic performance and environmental performance in one index. However, claimed as easy-acceptance by business practitioners, studies related with this term are still quite rare. Alternatively, as integrated economic-environment performance measurements, terms: Environmental Productivity and Eco-efficiency are more popular. This paper presents state-of-the- art of these terms to analyze them through case studies, method developments and level of studies related. Wish that a well distinction of these terms would help researchers used them properly.

Keywords **:** *Green productivity index, Environmental productivity, Eco-efficiency*

1. Introduction

Increasing concern for environment protection creates some consensuses, regulations, policies and strategies that enforce companies to consider their impacts to the environment by enhancing their environmental performance. This purpose seems impossible, in view of the fact that companies consider it as burdened costs without any gains. For this situation, Asian Productivity Organization (APO) in 1996 introduced a concept of Green Productivity (GP) that offers a simultaneous gain of economic and environment.

GP is a strategy for enhancing productivity and environmental performance for overall socio-economic development. It is an application of appropriate productivity and environmental management policies, tools, techniques, and technologies in order to reduce the environment impacts of an organization activities, good and services [1]. Since its objective is enhancing productivity and environmental performance simultaneously, this concept is more acceptable for the companies. It helps companies to be involved in environment protection without sacrificing their economic performance through efficient resource utilization and pollution prevention.

Towards GP measurement and improvement, Hur, et al. developed a measurement tool that indices economic and environmental performance in one index called GP index. As a ratio of system productivity to its environmental impacts [2], with this index, companies can estimate their economic and environment performance at once. Adopting this index, Gandhi, et al. use weighted environmental impact for their case study [3]. However, studies related with GP measurement or GP index term is still quite rare, similar terms such as eco-efficiency and environmental productivity are more popular to be used in some researches.

Using 'productivity' as economic performance measurement, GP index actually developed from eco-efficiency concept. Originally, eco-efficiency is a ratio of product or service value added to its environment influence [4],[5]. As an economic performance, 'product or service value added' is modified to be 'productivity' as a broader sense of efficiency in resources utility with quality improvement included [1]. Environmental productivity is another term that considered to be a similar term to GP measurement, since being 'green' in 'green productivity' means being 'environmental' in 'environmental productivity'. There is no significant definition of environmental productivity, but by its applications in many studies, it refers to Total Factor Productivity (TFP) in production efficiency theory developed by Farrell as in [6-8]. Unlike GP measurement term, Eco-efficiency and Environmental productivity have evolved and even had a cross-method applications in Malmquist index, e.g [9] and Data Envelope Analysis (DEA) method, e.g [10].

For some differences in their method developments and applications in some case studies, these three terms need significant distinction for proper applications and developments. Through this paper these of integrated economic – environmental performance measurement terms: GP measurement, Eco-efficiency, and Environmental productivity will be discussed in order to distinct them by defining and discussing their application in some case studies.

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2. Eco-efficiency

Eco-efficiency, first introduced by World Business Council of Sustainable Development (WBCSD) in 1992 is a business link to Sustainable Development [5]. It is an instrument for sustainability analysis [11]. As a concern in environment resource depletion by the business practitioners, eco-efficiency assesses the sustainable development in business view with focusing in resources saving and less environmental impact. Eco-efficiency is expressed as in (1) [4]:

$$\text{Eco-efficiency} = \frac{\text{Product or service value}}{\text{Environmental influence}} \quad (1)$$

In generalized definition, eco-efficiency of production is dealing with capability to produce goods and services while causing minimal environmental degradation [10]. Research areas of eco-efficiency are justifying indicators of numerator and denominator as in (1), method development, and implementation of eco-efficiency concept.

2.1. Justifying indicators of eco-efficiency

There are two indicators to measure an eco-efficiency. First, economic indicator is numerator in eco-efficiency ratio, and second, environmental indicator is denominator of eco-efficiency ratio as in (1). These two indicator are justified to encompass three different levels of eco-efficiency case studies: micro, macro and meso level where measurement is conducted.

Micro level is company level, in this level, eco-efficiency helps companies to predict their performance and make decisions about production factors or technology appropriate for their sustainability. Macro level is something related with government, regional, national or international, which have broader aim of sustainability, in this level decisions about sustainability have to be relevance with rising social quality of life. Decisions in micro level can affect macro level optimal sustainability, so policies and regulations are required to optimize the sustainability [11]. Meso level is related with sectoral level or industry groups. Eco-efficiency in this level is associated with sustainability among industry groups relation, product flows from upstream until downstream industries, waste utilization among them, etc. Regional government could be a meso level when related with broader level like national government.

Economic indicators of micro level are about product or service value, such as: net sales [12], production per year [13] or gross value added [14]. Meso level can be regional or sectoral level of research area conducted. At Regional level, almost the same with National level, economic indicators are about Gross Domestic Product (GDP) or Input-output matrix. Sectoral level includes group of several companies in similar products or process, so it has similar economic indicator with micro level, e.g. [15-17].

Environmental indicators at all levels are associated with environmental theme of each unit which depend on products, processes or services involved. Some studies use Life Cycle Analysis (LCA) method or guidance to determine their environmental indicators, e.g. [13-14, 16]. These environmental indicators include emissions, pollutions, resources and energy use. Emissions are related with Global Warming Potential (GWP) such as CO_2, CH_4, N_2O, e.g [14]. Eutrophication which covers all potential impacts of environmental emission of N and P (NH_3 , PO_4 ,NO_3), e.g [13, 16]. Pollutions are related with acidifying pollutants, ecotoxicity, e.g [13, 16].To be different in their method developments and applications in some case studies, these three terms need significant distinction for proper applications and developments. Through this paper these of integrated economic – environmental performance measurement terms: GP measurement, Eco-efficiency, and Environmental productivity will be discussed in order to distinct them by defining and discussing their application in some case studies. Summary of eco-efficiency justified indicators can be seen at **Table 1** below:

Table 1. Summary of Eco-Efficiency Justified Indicators

	Year	Author/s	Economic Indicator	Environment Indicator	Level	Case Study
1.	2007	Pagan and Prasad	Value added component	Water supply, Waste water discharge cost, Energy, Energy supply cost, Solid waste management	Meso	Food Processing Industry in Queensland
2.	2008	Kharel and Charmandusit	Net sales	Energy intensity, material consumptions, water use, waste generation, CO_2 emission	Meso	Iron rod Industry in nepal
3.	2008	Zhang, et al.	GDP, value added of industry	Water resource, Raw mining resource, Energy, COD discharge, Nitrogen discharge, Sulphur dioxide emission, Dust emission, Industrial solid waste	Meso	Industrial system in China

No.	Year	Author/s	Economic Indicator	Environment Indicator	Level	Case Study
4.	2009	Mens, et al.	Kg milk/ha	GWP, Eutrophication, Acidification, Energy used	Micro	Milk production in New Zealand
5.	2011	Middelaar, et al.	Gross value added	Energy use, GWP, Land use, Fossil energy use	Micro	Dutch Semi-hard cheese
6.	2011	Charmondusit and Keartpakpreak	Net sales	Water use, Material indicator, Hazardous waste, Energy	Meso	Petroleum and Petrochemical Group Thailand

Since social aspects are very important in macro level, Mickwitz, et al. proposed a social indicator development for regional eco-efficiency [18]. Although this indicator is already used in some studies of sustainability, e.g [19-20], embedding this indicator to eco-efficiency ratio is still debatable.

2.2. Method development of eco-efficiency

Eco-efficiency ratio is maximizing output (value added) to its minimize input (environment influence). It needs specific methods when dealing with more than one outputs or inputs. Adopting concept of TFP (explained at next section), Kuosmanen and Kortelainen proposed DEA method to aggregate environmental pressure into single environmental damage index[10], besides aggregating environmental pressure, DEA was used to cope unavailable price data of gases emissions. This method then extended by Kortelainen using Malmquist index with technology and efficiency changes influence[9]. Completing TFP method for more than one outputs or inputs, Lauwers proposed Material Balance Principle (MBP) method based on [7]:

$$M = R^{d} = R\text{-}R^{r} \qquad (2)$$

As seen in (2), M is the raw materials extraction from environment and R^{d} the materials that are disposed of in the environment, M are the net throughput of the system, R and R^{r} those parts of the materials flow that leaves the economic activities and are recycled.Opportunity cost based analysis of corporate eco-efficiency is proposed method by Hahn, et al. in order to ease eco-efficiency translation to managerial term and allow to quantify the drivers behind changes in corporate eco-efficiency [21].

Another eco-efficiency method that focused in resource saving is Factor X method. Actually this method is proposed for sustainability design product since 1994 by Wuppertal Institute[1, 22]. This method then used by Aoe as alternative eco-efficiency method to analyze ecodesign in electrical and electronic products [22].

Focus on market value of ecodesign rather than production process, Recency, Frequency and Monetary (RFM) based eco-efficiency analysis was proposed by Chen by analyzing customer feedback of sold ecodesign product [23].

3. Green Productivity (GP) Measurement

GP measurement is a measurement tool used to measure performance of GP implementation. As a strategy of enhancing productivity and environmental protection, GP applies productivity measurement tools and environmental management tools to analyze productivity and environmental performance separately.

For practical purpose, Hur,et al. proposed GP index as GP measurement in integrated fashion [2]. This tool was developed based on eco-efficiency ratio (1) by extending the numerator of ratio to be 'productivity' then decomposed as 'Selling Price/Life Cycle Cost' for their case study in polystronomer production as seen in and expressed in (4):

$$GP\text{index} = \frac{Selling\ price/Life\ cycle\ cost}{\text{Environmental Impact}} \qquad (4)$$

Adopting GP ratio, Gandhi,et al [3]. justified the 'Environmental Impact' by weighting the environment indicator of Solid Waste Generation (SWG), Gaseous Waste Generation (GWG), Water Consumption (WC) as seen in (5) :

$$GP\text{index} = \frac{Selling\ price/Life\ cycle\ cost}{w1SWG + w2GWG + w3WC} \qquad (5)$$

As integrated economic-environment performance, only few studies using GP index or GP measurement term. It is indicated that GP measurement separately of economic-environment performance is preferable.

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4. Environmental Productivity

Productivity as a common economic performance measurement has been used since 1900s [24]. Strict regulation of environment, enforce companies and governments to embed environment to their productivity measurement. This term focuses on desirable and undesirable output. Desirable output is an output as output we know, while undesirable output refers to waste or negative output that always stick together with the desirable output.

4.1. Method development of Environmental Productivity

The importance of undesirable output was first recognized by Shepard in 1970 [25]. This finding of undesirable outputs, challenges the researcher to separate these outputs in productivity measurement. Qi, et al. used shadow prices in their Green GDP measurement to represent depletion in natural resources and social welfare indicator [26]. This shadow prices then completed with distance function by Aiken and Pasurka [27]. Literature review by Kumar said that some of these studies treated the bad output as input, bad output as synthetic output such as pollution abatement. Then, Murty and Russell argued that treatment of bad output as input is not consistent with the material balance approach. Chung, et al. tried to use directional distance function to estimate production relationships involving good and bad output while treating them asymmetrically [28-29].

Calculating TFP of multiple inputs, multiple output most popular method is Malmquist index, but only valid when all output are good. As described at **Table 2**, Atkinson and Dorfman used Bayesian measurement to minimize entropy distance subject, while Kumar extended the Malmquist index to be Malmquist-Luenberg which offers alternative way of assigning weightage on the relative importance of the bad outputs [28, 30-31]. Other modification of TFP method is using Green TFP, e.g [31] or Environmentally adjusted TFP, e.g [25, 29] proposed by Reppeto, et al at 1996.
Other method development studied is presented in **Table 2** below :

Table 2. Summary of method development and case studies of Environmental Productivity

No.	Year	Author/s	Level	Method	Findings	Case study
1	2001	Qi,et al.	Macro	Integrated Environmental-economic Analysis of GDP and Productivity	Shadow prices of environmental input	-
2	2003	Aiken and Pasurka	Meso	Adjusted TFP	Distance function and shadow prices	Two-digit SIC USA
3	2005	Atkinson and Dorfman	Macro	Bayesian measurement	Limited Information likelihood by minimizing entropy distance subject	Electric utility
4	2006	Kumar	Macro	Malmquist-Luenberg Index	Directional distance function and technical and efficiency change	41 developed and developing countries 1971-1992
5	2007	Cao	Meso	Green TFP index	Welfare based green TFP	China's manufacturing sector
6	2007	Nanere, et al.	Meso	Environmentally adjusted TFP	Credible approach of environmental adjusted TFP	Agricultural Sector Australia
7	2008	Managi and Jena	Macro	Kuznet Curve	Kuznet curve type of relationship between environmental productivity and income	India
8	2009	Kumar and Khanna	Macro	Production Frontier Analysis (Distance Function)	Estimate cost of pollution abatement	Annex-1 and non Annex-1 countries 1971-1992

5. Do they measure the same things? (Conclusions)

This paper discussed three terms of Integrated Economic-Environmental Performance: Eco-efficiency, GP index and Environment Productivity through level of researches conducted and method development. In broad sense these terms measure the same thing: Green Productivity. According to APO [1], productivity is how efficient and effective we use resources as input to produce product or services needed by society. And being 'green' in our productivity means to be productive with minimizing environmental impact.

However, being similar and measure the same things, these terms still have dissimilar orientation in their application. Eco-efficiency and Green productivity are more applicable in micro level performance measurements for their simple application and adjustable. Environment Productivity is more complex and applicable in macro and meso level (see **Table 2**). It encompasses multiple output – input, technology change and inefficiency. Fortunately eco-efficiency has begun developed to be applicable in macro level by applying appropriate methods[9-10] (see **Table 1 and 2**)

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