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ANALYSIS

# Environmentally sensitive productivity growth: A global analysis using Malmquist–Luenberger index

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**Abstract**

We examine conventional and environmentally sensitive total factor productivity (TFP) in 41 developed and developing countries over the period of 1971 to 1992. Due to the non-availability of reliable input and $CO_2$ emissions price data, the study uses directional distance function to derive Malmquist–Luenberger (ML) productivity index. The index allows us to decompose the TFP into measures of technical and efficiency changes. DEA is used to compute the directional distance functions. We find that TFP index value is not different when we account for the $CO_2$ emissions relative to the situation when they are freely disposable. But for the components of TFP change: technical and efficiency changes, the null hypothesis of whether the indexes are the same under two different scenarios cannot be accepted. Issues of catch-up and convergence, or in some cases possible divergence, in productivity are examined within a global framework. The paper also studies the impact of openness on conventional and environmentally sensitive measures of productivity.


*Keywords:* Total factor productivity; Malmquist–Luenberger index; Environmentally sensitive productivity; DEA; Convergence hypothesis; Openness

*JEL classification:* D24; O47; C61; Q25; Q43

## 1. Introduction

Concerns about the impact of climate policy on 'productivity' or 'economic growth' have made countries hesitant about reducing $CO_2$ emissions. Climate policy has different dimensions: economic, technological and ecological. The economic dimension offers solutions in terms of price signals and the technological dimension sees solutions in terms of appropriate technological development and adoption. The ecological dimension adopts a more holistic view of man–nature relationship and calls for 'green accounting' or 'sustainable development'. This paper tries to present an extension of economic approach that includes aspects of technological development and adoption as well as green accounting.

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Productivity has acted as a significant engine of growth, allowing living standards in the world to advance rapidly throughout the twentieth century. However, its traditional measures do not account for production of harmful by-products such as $CO_2$, which may lead to environmental damage. It is conventionally measured using index numbers, which require data on prices of all outputs and inputs and the price information for bad outputs does not exist. The distance function approach can help overcome such problems as it requires data only on quantities of inputs, outputs and pollutants. Unlike this study, others estimating productivity using the distance function approach have focused on desirable outputs only (e.g., Färe et al., 1994b; Lall et al., 2002). There are also cases that have used micro-economic in contrast to macro-economic data used by the present study while estimating the total factor productivity (TFP) in the presence of bad outputs (e.g., Yaisawarng and Klein, 1994; Ball et al., 1994; Chung et al., 1997; Hailu and Veeman, 2000).

A method of measuring TFP using distance function that is growing in popularity is the use of Malmquist indexes. However, incorporation of bad outputs into the Malmquist indexes can be problematic. As the Malmquist indexes are based on Shepherd distance functions, which are radial in nature, firms cannot be credited with the reduction of bad outputs. This does not allow for changes in technology reducing the amount of pollution generated while increasing production of good outputs. It does not capture any "de-coupling" of the production of good outputs with bad outputs. If there has been a de-coupling of pollution and production, then there may be computational problems using the Shepherd distance function (Chapple and Harris, 2003).

There are several studies on the measurement of productivity changes in industries, which produce good and bad outputs simultaneously during the production process. Some of these studies have treated the bad outputs as inputs,[1] while the others have treated these as synthetic output such as pollution abatement (e.g. Gollop and Roberts, 1983). Murty and Russell (2002) have pointed out that the treatment of bad outputs as inputs is not consistent with the materials balance approach. The approach adopted by Gollop and Robert to treat the reduction in bad output as good output creates a different non-linear transformation of the original variable in the absence of base constrained emission rates (Atkinson and Dorfman, 2002). To overcome this problem, Pittman (1983) proposed that good and bad outputs should be treated non-symmetrically. He suggested the maximal radial expansion of good outputs and contraction of bad outputs. Chung et al. (1997) have used the directional distance function to calculate production relationships involving good and bad outputs that treats good and bad outputs asymmetrically. This study follows Chung et al. (1997) and uses directional distance function to measure Malmquist–Luenberger (ML) productivity index and its components.

The components of productivity index—technical and efficiency changes are analogous to the notions of technological innovation and adoption, respectively. The ML index credits producers for simultaneously increasing good outputs and reducing the production of bad outputs such as $CO_2$. It also offers an alternative way of assigning weightage on the relative importance of the bad outputs which can be interpreted as if consumers have preferences for reducing bad outputs regardless of the actual damage resulting from these products (Färe et al., 2001). Although the ML index does not directly relate to changes in welfare level, it does provide a complete picture of productivity growth under environmental regulations of emissions that are of concern to society.

The measures of productivity are often obtained under alternative assumptions about the disposability of $CO_2$. That is, it could be either strongly or weakly disposable. While, strong disposability implies that a country can reduce $CO_2$ emissions without incurring any abatement costs, weak disposability assumes diversion of resources from the production of good outputs. Thus the ML index encompasses green accounting while accounting for undesirable outputs.[2]

[1] Cropper and Oates (1992), Pittman (1981), Haynes et al. (1993, 1994), Boggs (1997), Kopp (1998), Reinhard et al. (1999), Murty and Kumar (2004), etc.

[2] Hailu and Veeman (2000) termed the measurement of productivity under weak disposability of pollutants as environmentally sensitive productivity.