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Interfaces with Other Disciplines

Productivity change using growth accounting and frontier-based approaches – Evidence from a Monte Carlo analysis

Dimitris Giraleas *, Ali Emrouznejad, Emmanuel Thanassoulis

Operations and Information Management, Aston Business School, Aston University, Birmingham, UK

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ABSTRACT

This study presents some quantitative evidence from a number of simulation experiments on the accuracy of the productivity growth estimates derived from growth accounting (GA) and frontier-based methods (namely data envelopment analysis-, corrected ordinary least squares-, and stochastic frontier analysis-based malmquist indices) under various conditions. These include the presence of technical inefficiency, measurement error, misspecification of the production function (for the GA and parametric approaches) and increased input and price volatility from one period to the next. The study finds that the frontier-based methods usually outperform GA, but the overall performance varies by experiment. Parametric approaches generally perform best when there is no functional form misspecification, but their accuracy greatly diminishes otherwise. The results also show that the deterministic approaches perform adequately even under conditions of (modest) measurement error and when measurement error becomes larger, the accuracy of all approaches (including stochastic approaches) deteriorates rapidly, to the point that their estimates could be considered unreliable for policy purposes.

1. Introduction

The study of productivity is a very important topic. The UK Office of National Statistics (ONS, 2007) states that: ‘Statistics relating to productivity are vital to understanding the economy and how it changes’. It also states that: ‘it is crucial that both experts and the general public can depend on the accuracy and relevance of ONS productivity measures’. The Organisation for Economic and Social Development (OECD) also states that one of its major aims is to improve the measurement of productivity growth.[1]

The pursuit of productivity growth and productivity convergence is also one of the central goals of the European Union (EU). Probably the main instruments to achieve those goals are the so-called Structural funds, which are distributed based on Gross Domestic Product (GDP) per capital differentials between the various EU regions. Changes in GDP per capital are also used as simple measures of productivity growth and although probably sufficient for setting policy at this stage, a more refined productivity indicator is required to evaluate the effects of the funds and the degree of convergence. The issue of converge is critical, since the underlying aim of the Structural funds is to increase GDP by providing the relatively poorer regions with the tools to achieve the productivity/efficiency potential of the more advanced regions, rather than raising GDP simply through factor accumulation (i.e. increasing input quantities).

More complex approaches that seek to estimate Total Factor Productivity growth (TFP) can provide the required granularity of information, by examining the sources of GDP growth that are not due to such factor accumulation. The EU seems to support the development and use of such approaches, given the emphasis the Directorate General for Economic and Financial Affairs (DG-ECFIN) has placed on the EU KLEMS project (EU KLEMS, 2008), an EU-wide research project that aims to provide estimates of aggregate TFP growth in the EU member states together with the data necessary for the estimation. The DG-ECFIN (Koszerek et al., 2007) states that the productivity indicators provided by EU KLEMS are ‘*essential for understanding recent EU productivity trends*’, ‘*fundamental in assessing progress with the Lisbon Strategy*’, ‘*can complement the ''Structural Indicators'' Programme*’, and ‘*provide an additional data source for refining the potential growth rate estimates used in the EU's budgetary surveillance process*’.

Productivity growth in the EU KLEMS database is estimated based on growth accounting (GA). GA is an index number-based methodology for measuring productivity growth which is based in the early work of Tinbergen (1942) and independently, Solow (1957) and is the method of choice when measuring aggregate (i.e. country- or sector-wide) productivity growth for most interested agents, namely statistical agencies (national and international), central banks and government bodies (see for example

* Corresponding author.
E-mail address: giralead@aston.ac.uk (D. Giraleas).

[1] http://www.oecd.org/about/0,3347,en_2825_30453906_1_1_1_1_1,00.html, accessed 14 January 2011.

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the US Bureau of Labour Statistics technical note on multifactor productivity[2] and ONS, 2007). A major factor in the widespread adoption of GA is the fact that estimates can be (relatively) easily produced using country- or sector-specific National Accounts data, without recourse to information from outside the country or the sector examined; on the other hand, GA requires the adoption of a number of simplistic (potentially unrealistic) assumptions, most notably those relying on the existence of perfect competition, which could lead to unreliable estimates.

Given the stated need for accurate productivity growth estimates, the first aim of this study is to assess the impact on the accuracy of the GA estimates when some of the assumptions central to the notion of perfect competition are violated. This is achieved by undertaking a number of simulation experiments, which utilise randomly generated data for which the parameters of interest (most importantly productivity change) are known a priori; when GA (or any other productivity change measurement approach) is applied to the same dataset, a measure of the overall accuracy of the approach can be devised by comparing the estimate of productivity change to its true value.

Frontier-based methods offer an attractive alternative for the measurement of aggregate productivity change. Unlike the more traditional GA methods, they allow for the production to occur inside the frontier, thereby explicitly allowing for inefficiency in the production process and relaxing the stringent assumptions required when using growth accounting methods. In addition, frontier-based methods also allow for the decomposition of productivity growth, which could be of great interest to the users of productivity change estimates.

There are a number of applications of frontier based methods for the measurement of aggregate productivity growth in the academic literature. Färe et al. (1994) was one of the first studies that utilised Data Envelopment Analysis (DEA), the more widely-used non-parametric frontier based approach, to construct Malmquist indices of productivity growth; the approach has since been adopted in numerous other studies (for a comprehensive list of applications of DEA-based Malmquist indices see Fried et al., 2008 and Del Gatto et al., 2008). Kumbhakar and Lovell (2000) introduced another way to construct a Malmquist index of productivity growth that relies on parametric frontier models, such as Corrected Ordinary Least Squares (COLS) and Stochastic Frontier Analysis (SFA); such models have also been widely used in the literature (see Sharma et al., 2007, for a list of sample studies).

However, despite the adoption of such frontier-based methods in the academic literature and the theoretical advantages offered by frontier-based methods compared to the more traditional GA approach, there has been limited research on quantifying whether these advantages translate into improved accuracy of the resulting productivity change estimates and under which conditions one frontier-based approach is more accurate than another. As such, the second aim of this study is to employ the aforementioned simulation experiments to provide quantitative evidence on the accuracy of the more widely adopted frontier-based approaches, namely DEA-, COLS- and SFA-based Malmquist indices, under a number of conditions that violate the assumptions made under perfect competition.

In more detail, this research aims to examine the accuracy of both GA and frontier-based productivity change estimates:

- when technical inefficiency, in various degrees of severity, is present,
- when inputs and prices are volatile from one period to the next,
- when the production function is misspecified, and finally
- when the factors of production are measured inaccurately (again in various degrees of severity).

[2] http://www.bls.gov/mfp/mprtech.pdf, accessed 14 January 2011.

2. Methodology of the current research

2.1. Productivity measurement approaches considered

Each simulation experiment examines the performance of the following approaches:

- GA,
- DEA-based circular Malmquist indices,
- COLS-based Malmquist indices, and
- SFA-based Malmquist indices, (only when measurement noise is included in the experiment).

All frontier-based approaches examined in this analysis rely on the notion of what has come to be known as the Malmquist productivity index (Diewert, 1992), which has been used extensively in both the parametric (see for example Kumbhakar and Lovell, 2000) and the non-parametric (see for example Thanassoulis, 2001) settings. Furthermore, the productivity index produced by GA can be considered as a special case of the Malmquist productivity index (see OECD, 2001).

Given the nature of the approaches considered, all of the analyses we perform focus on the production side of the economic process.

2.1.1. Growth accounting

Growth Accounting (GA) is an index number-based approach that relies on the neo-classical production framework, and seeks to estimate the rate of productivity change residually, i.e. by examining how much of an observed rate of change of a unit's output can be explained by the rate of change of the combined inputs used in the production process. There are many modifications that could be applied to the more general GA setting (Balk, 2008; Del Gatto et al., 2008); however, most applications still utilise 'traditional' growth accounting methods, as described in OECD (2001) (see for example O'Mahony and Timmer, 2009).

GA postulates the existence of a production technology that can be represented parametrically by a production function relating gross output (Y), to primary inputs labour (L) and capital services (K) as well as intermediate inputs such as material, services or energy (M).

$$Y = F(K, L, M) \tag{1}$$

If gross output is measured net of intermediate inputs, i.e. using a Gross Value Added (GVA) measure, (1) becomes:

$$Y_{GVA} = F(K, L) \tag{2}$$

GA assumes that productivity changes (TFP) are Hicks-neutral type, i.e. they correspond to an outward shift of the production function, such that:

$$Y_{GVA} = F(K, L) \times TFP \tag{3}$$

A number of assumptions are required to parameterise (3), namely that:

- the production function is Cobb-Douglas and exhibits constant returns to scale;
- each assessed unit minimises the costs of inputs for any desired level of output and can adjust the level of primary inputs that it utilises at any moment and without additional costs;
- input markets are perfectly competitive and all production happens on the frontier;
- all relevant inputs and outputs are taken into account and measured without error.