DATA ISSUES IN TOTAL FACTOR PRODUCTIVITY BENCHMARKING: A CENTRAL EUROPEAN PERSPECTIVE

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Total factor productivity is a method of measuring overall productivity of businesses, industries or economies. It is an approach which is recently becoming popular among government regulatory agencies when applying the so-called performance-based regulation. This principle induces regulated companies (for instance, electricity or natural gas distributors) to behave efficiently even if their industries are not exposed to competitive pressures, since they are rewarded for being more productive than other firms in the industry, and penalized in the opposite case.
The aim of this article is to deal with the question what are the main data issues when comparing total factor productivity among firms or industries with focus on the Central European region, which is very heterogeneous in terms of geographic, social, economic and historic conditions.
In the first part, we introduce total factor productivity and the most common methods of its measurement – Malmquist and Törnqvist indexes. Consequently, we divide the data issues into separate categories and discuss them more in detail. The first category of issues is related to defining the set of comparable firms. Many factors, such as the degree of competition in the market, the extent of government regulation, economies of scale, firm size, geographical conditions and historic development have to be taken into consideration. The second category is associated with specifying the time period. TFP estimates should be based on long time series and the period should include the whole business cycle and be representative and exclude extraordinary events. The third group of issues is related to defining and measuring the inputs and outputs. Since a number of difficulties are associated with labor input measurement, it is often included into operating expenditures along with materials and services. The measurement of capital is even more contentious. The outputs should reflect performance, complexity and quality of service rendition. Finally, the fourth category of problems concerns determining the costs of inputs and outputs (cost-based indexes) or defining and measuring the reference technology (distance-based indexes), where some degree of arbitrary judgment and inaccuracy is inevitable.
We conclude with the suggestion to avoid methods requiring large time series such as frontier-based methods of efficiency benchmarking (data envelopment analysis or econometric methods) or Malmquist TFP benchmarking in the Central European region due to huge differences between firms and their environment. However, the question of the best performing regulatory methods is still not clarified and is subject to intensive academic debate.

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1. Introduction

Productivity assessment is an important tool both for firms, which need to evaluate their performance in order to find weaknesses and improve their position in the market, and for regulatory agencies, which need to assess efficiency of firms being regulated by the government. Total factor productivity is an approach which takes into account all inputs and outputs of the evaluated firm and aggregates them into a single scalar value. Productivity measurement has recently become popular among government regulatory agencies when applying the so-called **performance-based regulation**. A regulated firm's productivity growth is compared with the productivity growth of other firms in the industry. When the firm succeeds to improve its

productivity more than other firms, it is rewarded by greater allowed revenues. This principle, often referred to as **regulatory benchmarking**, induces regulated companies (for instance, electricity or natural gas distributors) to behave efficiently even if their industries are not exposed to competitive pressures. Most frequently, total factor productivity is measured by indexes of productivity. The results, however, are dependent upon the quality of data.
This issue is particularly evident in heterogeneous regions such as the Central Europe. The aim of this article is to deal with the question what are the main data issues when comparing total factor productivity among firms or industries with focus on the Central European region, which traditionally includes Czech Republic, Slovakia, Hungary, Poland, Germany, Austria and Switzerland. In the first part, we will introduce total factor productivity and the most common methods of its measurement – Malmquist and Törnqvist indexes. Consequently, we will divide the data issues into separate categories and discuss them more in detail.

2. Total Factor Productivity and its Measurement

Traditionally, productivity is defined as a ratio of output over input. The total factor productivity (TFP) approach takes into account all outputs and inputs of the evaluated firm. Therefore, it is necessary to aggregate the set of outputs and outputs so that productivity becomes scalar value. In practice, TFP is measured by productivity indexes or productivity indicators. Indexes have multiplicative form, whereas indicators have additive form. The measures can be based either on distance function, or on price aggregation. Among measures based on distance function, we can cite Malmquist productivity index (Caves et al. 1982), Hicks-Moorsteen productivity index (Diewert 1992: 240) and Luenberger productivity indicator (Chambers 1996). The most common TFP measures which are based on price aggregation are Törnqvist productivity index (Törnqvist 1936), Fisher productivity index (Fisher 1922) or Bennet-Bowley productivity indicator. In this article, we will deal with two most frequently used TFP measures, Malmquist and Törnqvist indexes.

Malmquist index of productivity

A produced can be defined as an entity transforming a set of inputs $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ into a set of outputs $\mathbf{y} = (y_1, y_2, \ldots, y_m)$. In order to define Malmquist index, we have first to introduce the notion of efficiency. **Efficiency** of a firm can be defined as a ratio of observed values of inputs and outputs and their optimal values. The analysis of efficiency can be oriented either on minimizing inputs with given outputs or maximizing outputs with given inputs. The production technology can be represented using a set of couples (input-output vectors)

$$T = \{(\mathbf{x}, \mathbf{y})\}, \text{ where x is input to produce y.} \tag{1}$$

Another possible representation of production technology is the output requirement set P(x), e.g.

$$P(x) = \{\mathbf{y} : (\mathbf{x}, \mathbf{y}) \in T\} \tag{2}$$

As a measure of efficiency, we can use the Debreu-Farrell approach (Debreu 1951; Farrell 1957). Using the above-described notation, we can define the Debreu-Farell measure of technical efficiency as the maximum possible equiproportional increase of given output so that it still belongs to the output requirement set.

$$TE(\mathbf{x}, \mathbf{y}) = \max\{\Phi : \Phi\mathbf{y} \in P(x)\} \tag{3}$$

The inverse value of technical efficiency is called distance function.

$$D(\mathbf{x},\mathbf{y}) = \min\{\lambda : \mathbf{y} / \lambda \in P(x)\} \tag{4}$$

When applying the output-maximizing approach, the lesser the distance from a production frontier, the better is the efficiency score. In the real world, the production frontier is unknown and has to be estimated using econometric methods (e.g. corrected ordinary least squares, COLS) or mathematical programming (e.g. data envelopment analysis, DEA). Using the above described definitions, we can define the Malmquist index of productivity. Consider a period during which the production has changed from $(\mathbf{x_t},\mathbf{y_t})$ to $(\mathbf{x_{t+1}},\mathbf{y_{t+1}})$. The Malmquist index of productivity for period *t* , respectively for period *t+1,* would be the ratio

$$\begin{aligned} M_t(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) &= \frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \\ M_{t+1}(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) &= \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}; \end{aligned} \tag{5}$$

If the technology has changed during the period, these two indexes would result in different values. Therefore, it is common to employ the geometric mean of the two indexes and specify the **Malmquist index of productivity** as

$$M(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) = \sqrt{\frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}} \tag{6}$$

Malmquist index is of great theoretical importance. However, it is necessary to estimate the real but unknown production frontier using econometric or mathematical programming methods.

Törnqvist index of productivity

Törnqvist index is an example of indexes which can be calculated from observed empirical data without having to estimate the unknown production frontier. These indexes are often called superlative indexes. Under certain conditions (see Färe et al 2008: 564), they approach Malmquist index. The calculation is based on observed prices (weights) of input and output factors. Let w = $(w_1,w_2,\ldots,w_n)$ denote the prices of inputs and **p** = $(p_1,p_2,\ldots,p_m)$ denote the prices of outputs. Törnqvist index of productivity is defined as a ratio of output quantity index Y_T and input quantity index X_T . Usually, the two quantity indexes are specified in their logarithmic form as

$$\begin{aligned} \ln Y_T &= \frac{1}{2}\left(\sum_m \left[\frac{p_{m,t}\,y_{m,t}}{\sum_m p_{m,t}\,y_{m,t}} + \frac{p_{m,t+1}\,y_{m,t+1}}{\sum_m p_{m,t++}\,y_{m,t+1}}\right] \ln\frac{y_{m,t+1}}{y_{m,t}}\right) \\ \ln X_T &= \frac{1}{2}\left(\sum_n \left[\frac{w_{n,t}\,x_{n,t}}{\sum_n w_{n,t}\,x_{n,t}} + \frac{w_{n,t+1}\,x_{n,t+1}}{\sum_n w_{n,t++}\,x_{n,t+1}}\right] \ln\frac{x_{n,t+1}}{x_{n,t}}\right) \end{aligned} \tag{7}$$

And finally, the **Törnqvist index of productivity** can be specified as

$$\Pi_T = \frac{Y_T}{X_T} = e^{\ln Y_T - \ln X_T} \tag{8}$$

3. Data Issues of TFP Benchmarking

Robust and reliable TFP estimates depend substantially on the availability of long term and reliable information on input and output measures, ideally for a large number of firms operating in the relevant industry. This approach involves multiple issues which we will discuss in this section. First, a set of comparable firms has to be chosen and the time period has to be specified. Then, as follows from the definitions of productivity indexes, it is necessary to define the appropriate set of inputs and outputs, which have to be measured accurately. In addition, production frontier (Malmquist index) or costs of inputs and outputs (Törnqvist index) have to be estimated. Besides these issues, other can arise from typographical errors, invalid observations and unusual observations that are real outliers (Coelli et al., 2005).

To sum up, we can divide the data issues into four categories:

- Defining the set of comparable firms;
- Specifying the time period;
- Defining and measuring the inputs and outputs;
- Determining the costs of inputs and outputs (cost-based indexes) or defining and measuring the reference technology (distance-based indexes).

3.1 Defining the set of comparable firms

The major issue arises when choosing a suitable set of comparable firms whose productivities will be compared against each other. A great number of factors are influencing each firm's performance (see e.g. Pedell 2006: 24). Some of them are related to the firm itself (size, ownership structure, capital structure, age and quality of assets) and others are related to the environment (inflation rate, interest groups, unemployment, purchase power, customer density etc.) For instance, regulated and competitive firms productivity should not be benchmarked since the productivity of competitive firm is likely to be higher (see e.g. Orazem and Vodopivec 2009) and similarly, the extent of government regulation affects productivity (Crafts 2006) which distorts international comparisons. The empirical evidence on the effects of firm size on productivity is mixed (compare e.g. Leung et al. 2008 and Dhawan 2001), however, economies of scale should be taken into consideration. Capital structure is also likely to affect performance; however, in Central Europe, debt is used to a lesser extent in Eastern countries than in Western countries (Machek 2011). The issue of age and quality of assets is particularly important when comparing developed countries and former states of the Eastern Bloc; in post-communist countries, the development was centrally planned which has an impact on nowadays quality and structure of assets and maintenance costs. Geographical conditions also affect costs; in mountainous countries such as Switzerland, the maintenance and construction costs are likely to be higher than in flat countries such as Hungary. The choice of adequate sample of firms seems to be the very challenging, however, in small countries, domestic data are not sufficient and international benchmarking has to be employed.

3.2 Specifying the time period

In general, productivity growth is more accurately measured in long term, since TFP can vary substantially from one year to another. The time period has to be representative, should include the whole business cycle and exclude any extraordinary events. For instance, Blanchard and Kremer (1997) found that increased competition in the countries of the former Eastern Bloc may have contributed to TFP decline because it disrupted the Warsaw Pact economic connections. Similarly, privatization of state-owned firms may cause a TFP decline, because the technology

gap may discourage enterprises restructuring (Angelucci et al. 2001). Furthermore, introduction or variation of regulatory regimes seems to reduce productivity, but in Central Europe, modern economic regulation has only a short history which further reduces the possibilities of reliable long-term TFP estimates. The lag between investment and its effects is also nonnegligible. Short-term results may look poor, because the effects of investments in infrastructure are not immediate (Brynjolfsson 1993).

3.3 Defining and measuring the inputs and outputs

There are many conceptual and practical issues in identifying the number and level of aggregation of inputs and outputs for each industry. Classical input factors which should be taken into account are labor, capital and materials.

Labor is most often measured by the number of employees or man-hours, which should be corrected, since outsourcing of activities can distort the results. Activities should be well defined and separated (for example, electricity distribution and sale). Moreover, employees can differ in their skills, education and experience, but more skilled employees contribute to the growth to a greater extent. It is preferable to distinguish among these categories of employees. Because of these difficulties, labor input is sometimes incorporated into operating expenditures (OPEX) which are taken as an aggregate measure of labor and materials.

The most contentious is the measurement of **capital**. The capital used in regulatory benchmarking has to fulfill several requirements in order to be included in the asset base (just and reasonable, useful, prudently incurred etc., see Lesser 2007). Moreover, as previously mentioned, the quality and age of capital may vary substantially, as well as its valuation methods. The capital is often measured directly and proxied by kilometers of wires (electricity distribution) or pipes (natural gas distribution) which are invariant to different depreciation schemes. However, the relation between these proxies and real capital stocks is not clear. Indirect measurement of capital is based on the value of assets, which raises the question of accurate and comparable valuation (especially replacement cost valuation methods versus historic cost methods). A good analysis of capital measurement and associated issues has been carried out e.g. by Coelli et al. (2005).

Outputs used in TFP estimates should represent the basket of services provided by regulated firms. Outputs of distribution companies should reflect how much is being transported, how far it is being transported, and the quality of service. The set of outputs should reflect both 'supply side' and 'demand side' (see Lawrence and Diewert 2006: 214). The definition of the quality aspect is particularly challenging, because there is not yet a definite way of incorporating common reliability and quality measures in TFP calculations, since it seems that increases in quality are reflected in a decrease of TFP rather than an increase. Moreover, as we already mentioned, investments in quality improvement make short-term results look poor, because the effects of investments are not immediate, and the investing firm is being penalized rather than rewarded.

There are more issues concerning availability of data and their accuracy and comparability. In tariff regulation, data are provided by regulated companies; it is logical to suppose that they not be perfectly accurate, since regulated companies seek to improve their own efficiency.

3.4 Estimating the costs of inputs and outputs or the production frontier

Usually, the costs, i.e. **weights of outputs** are derived from the share of each output in total revenue (in the case of competitive industries, where prices reflect marginal costs) or output cost shares (in the case of natural monopolies). The latter case is more complicated, since it involves either arbitrary judgments about the relative importance or econometric estimation of cost function (Lawrence and Diewert, 2006). There is an academic debate over which of these approaches performs the best. However, some degree of inaccuracy is practically inevitable. Similarly, the **weights of inputs** are represented by the share of each input in total costs. Capital

input costs can be calculated either directly from estimates of depreciation, opportunity costs and capital gains or indirectly as the residual between total revenue and OPEX, in which case the capital input variables have to be allocated according to their proportion in total asset value.
When distance-based TFP measures are employed, it is necessary to estimate the **production frontier**. This approach involves all inconveniences related to frontier methods such as COLS or DEA; especially the need of a large number of observations to obtain robust estimates, influence of noise and overall complexity. On the other side, these methods incorporate input and output weights implicitly and it is not necessary to estimate them.

5. Conclusion

In this article, we dealt with the question of the main data issues when comparing total factor productivity (TFP) among government regulated firms or industries with focus on the Central European region. This question is important both for regulatory agencies in deciding what regulatory methods to adopt, and for regulated firms in evaluating their own productivity, identifying weaknesses and threats and negotiating with regulatory agencies.
We divided the issues associated with TFP benchmarking into four categories. The first one is related to defining the set of comparable firms. Many factors, such as degree of competition, government regulation, economies of scale, firm size, geographical conditions and historic development have to be taken into consideration. The second challenge is associated with specifying the time period. TFP estimates should be based on long time series and the period should include the whole business cycle and exclude extraordinary events. The third group of issues is related to defining and measuring the inputs and outputs. Since a number of difficulties are associated with labor input measurement, it is often included into OPEX along with materials and services. The measurement of capital is even more contentious. The outputs should reflect performance, complexity and quality of service. The fourth category of problems concerns determining the costs of inputs and outputs or defining and measuring the reference technology, where some degree of arbitrary judgment and inaccuracy is inevitable.
Due to the difficulties associated with the heterogeneity of firms and their environment, which is especially evident in the Central European region, we suggest to avoid methods requiring large time series such as frontier-based methods of efficiency benchmarking or Malmquist TFP benchmarking. However, the question of the best performing regulatory method is still far from being clarified and is subject to intensive academic debate.

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