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DISCUSSION PAPER

Leibniz Institute of Agricultural Development in Central and Eastern Europe

AGRICULTURAL PRODUCTIVITY GROWTH IN THE EUROPEAN UNION AND TRANSITION COUNTRIES

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ABSTRACT

Malmquist total factor productivity (TFP) index has been extensively applied in the literature to measure productivity growth decomposition. This study applies a parametric decomposition of a Generalized Malmquist TFP index to measure and compare the levels and trends in agricultural productivity in European countries, making use of the most-recent data available from the Food and Agriculture Organization (FAO) of United Nations. The aim of this study is to measure TFP developments in agriculture of transition countries after breakdown of socialism and to compare their TFP growth with other European countries. The Generalized Malmquist productivity index can be decomposed into technological change, technical efficiency change and scale efficiency change. These measures will provide insightful information for policymakers in designing proper policies to promote a higher growth rate in agriculture in transition countries.

JEL: Q16, Q18, P27

Keywords: Transition countries, Malmquist, Multifactor Productivity, agriculture.

ZUSAMMENFASSUNG

PRODUKTIVITÄTSENTWICKLUNG IN DER LANDWIRTSCHAFT IN DER EUROPAÏSCHEN UNION UND IN DEN TRANSFORMATIONSLÄNDERN

Malmquist Total Factor Productivity (TFP) Index gehört zu den meist verwendeten Methoden der Produktivitätsanalyse und ihrer Zerlegung. In diesem Paper wird ein parametrisches Verfahren eingesetzt, um die Produktivitätsentwicklungen in der europäischen Agrarwirtschaft zu analysieren. Die statistische Datenbasis basiert auf der Datenbank der Food and Agriculture Organization (FAO) of United Nations. Das Ziel dieses Forschungsvorhabens ist es, die Produktivitätsentwicklungen in den Agrar- und Ernährungssektoren der Transformationsländern Mittel- und Osteuropas sowie der ehemaligen Sowjetunion zu messen und diese mit dem Wachstum in der Europäischen Union zu vergleichen. Methodisch kann Malmquist Index zerlegt werden in technical change, efficiency change and scale efficiency change. Dieser Zerfall des Indexes kann wichtige Informationen für die Politikgestalter und Forscher hinsichtlich der weiteren Entwicklung des Agrarsektors in betroffenen Ländern bringen.

JEL: Q16, Q18, P27

Schlüsselwörter: Transformation, Malmquist Index, Agrarsektor, Multifactor Productivity.

CONTENTS

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1 INTRODUCTION

The second half of 1989, with the fall of the Berlin Wall and a number of communist governments, brought dramatic developments in the process of collapse of the communist system in Eastern and Central Europe and the Soviet Union. In the late 1980s and early 1990s, in these countries, began major market-oriented reform of their planned economies. It is taking longer than predicted for the 28 countries in this region to make the full transition from centrally planned to market economies and from communist totalitarianism to open and democratic political systems. The transition process more accurate defined in COLOMBATTO (2002) "as the period of time it takes for new institutions and organisations to be introduced and upheld, for agents to learn how to operate according to a reformed system of property rights and adjust to hitherto virtually unknown rules of the game", affected also the whole agricultural sector in Central and Eastern European countries (CEECs). Transition affected the output and input levels in agriculture as well as the performances of farms, agribusiness chains and the overall sector. Agricultural output collapsed in almost all countries in the wake of the reforms (TRZECIAK-DUVAL, 1999). Rural incomes also declined steeply in most countries. Several authors already described the causes of the output decline in transition economies (BLANCHARD, 1998; MACOURS and SWINNEN, 2000; SWINNEN, 2002; TONINI, 2004). Some of the main causes of the output decline in the agricultural sector were a combination of worsening terms of trade consequent to price liberalisation and subsidy cuts, farm restructuring and privatisation, non-favourable weather conditions in some years, and a statistical bias in reporting agricultural output before and soon after the reform period (MACOURS and SWINNEN, 2000). The poor performance of socialised agricultures in term of factor productivity, technological progress and adequate food supply have been frequently attributed either to the socialist nature of agriculture or to the centralised economic system in which agriculture took place (BRADA and KING, 1993). Many studies surveyed in GORTON and DAVIDOVA (2004) have tried to connect for the CEECs the variation in farm efficiency to farm size, farm structure as well as to other factors (i.e. human and social capital, contracting, modernisation, part and full-time farms). Agricultural performance differences across transition countries were also a subject of investigations (TONINI, 2004; RIZOV, 2004; LISSITSA et al., 2006).

In the most studies large differences across countries with respect to productivity were observed. The divergences are considerable in the beginning of transition. Productivity growth began early in the 1990s in several of the CEECs. In contrast, stagnation and continued productivity declines characterised the entire agricultural transition period in Russia, Ukraine, and several other Former Soviet Republics FSU republics. (ROZELLE and SWINNEN, 2000). However, during past 4-5 years has seen sustained reform momentum across many countries and areas of transition, as measured by the EBRD's transition indicators (EBRD, 2005). A number of countries that had been lagging in reform, such as Bosnia and Herzegovina, the Federal Republic of Yugoslavia, Ukraine and Russia, have made significant progress over the past years as a result of favourable political and economic developments. In 2004, for the first time, Ukraine and Russia became net exporters of grain. Agriculture was the main force behind stellar growth rates in many countries of the region last years: 12 per cent for Ukraine, for example, and 7 per cent for Serbia and Montenegro.

The main purpose of this paper is to measure TFP developments in agriculture of transition countries after breakdown of socialism and to compare their TFP growth with other European countries. In the literature, TFP can be measured by using productivity index. The most widely-used productivity index is Malmquist TFP index presented in CAVES et al. (1982) and FÄRE et al. (1994). This Malmquist TFP index has become common in practice by applying two techniques such as non-parametric and parametric to calculate the TFP index. In this study, we employ a parametric approach to decompose the Malmquist TFP index into technical change, technical efficiency change and scale efficiency change. The study is empirically implemented by using a panel data set of the European agriculture on 46 countries over the time period of 1992-2002 to measure and compare the productivity growth among the European countries.

The remainder of this paper is organised as follow. In Section 2, the theoretical concept of the Malmquist TFP growth decomposition is presented, followed by a discussion of the methodologies to measure the Malmquist TFP index decomposition. Next, the methodology which is applied in this paper is concluded and then an empirical framework to the Malmquist TFP index decomposition is presented. Section 3 discusses the data set and the definitions of all variables used in this study. Empirical results are presented and discussed in Section 4 and then conclusions follow in the final section.

2 METHODOLOGY

TFP using productivity index is theoretically defined as the ratio of an aggregate output index to an aggregate input index. The most widely-used productivity index is Malmquist TFP index presented in CAVES et al. (1982) and FÄRE et al. (1994). The Malmquist TFP index measures the TFP change between two data points by calculating the ratio of two associated distance functions. Either nonparametric or parametric techniques can be applied to calculate the component distance functions defined in the Malmquist TFP index.

2.1 The Malmquist TFP Index Decomposition

The Malmquist TFP index is defined using distance function. Distance function provides a convenient way to describe a well-behaved multi-input multi-output production technology without the need to specify behavioral assumptions such as cost minimization or profit maximization. Consider a data set consisting of a vector of inputs and outputs for each of the *i*-th country where $i = 1,...,I$ denotes a country index. Let the input and output vectors for the *i*-th country be denoted $x_i = (x_{i1},...,x_{iN}) \in R_+^N$ and $y_i = (y_{i1},...,y_{iM}) \in R_+^M$, respectively. For any input vector $x \in R_+^N$ and any output vector $y \in R_+^M$, an input vector $x \in R_+^N$ is transformed into net outputs $y \in R_+^M$ by a production technology. This production technology can be defined using an output orientation $x \rightarrow P(x) \subseteq R_+^M$ where $P(x)$ represents the subset of all output vector $y \in R_+^M$ obtainable from x or less than x for any $x \in R_+^N$.

With a specific time period, t, the production technology S_t transforms inputs $x_t \in R_+^N$ into net outputs $y_t \in R_+^M$ for each time period $t = 1,...,T$. The production technology consisting of all feasible input-output vectors on the production possibility set at time t is defined as

$$S_t = \{x_t, y_t : y_t \leq f(x_t)\} \in R_+^{M+N} . \quad (1)$$

The distance function can be defined by rescaling the length of an input or output vector with the production frontier as a reference. The output distance function is defined as

$$D_t^o(x_t, y_t) = \min\{\theta : (x_t, y_t/\theta) \in S_t\}, \quad (2)$$

where $D_t^o(x_t, y_t) \leq 1$ if and only if $(x_t, y_t) \in S_t$. Furthermore, $D_t^o(x_t, y_t) = 1$ if and only if (x_t, y_t) is located on the outer boundary of the feasible production set which occurs only if production is technically efficient.

The output-orientated Malmquist TFP index as defined by Färe et al (1994) measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. The output-orientated Malmquist TFP change index between periods t and $t+1$ is the geometric mean of adjacent-period output-orientated Malmquist TFP index which is given by

$$m_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right) = \left[\frac{D_t^o\left(x_{t+1}, y_{t+1}\right)}{D_t^o\left(x_t, y_t\right)} \times \frac{D_{t+1}^o\left(x_{t+1}, y_{t+1}\right)}{D_{t+1}^o\left(x_t, y_t\right)} \right]^{1/2} \quad (3)$$

The above Malmquist TFP change index can be decomposed in a way that highlights what sources attributing to the TFP growth which can be written as

$$m_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right) = \frac{D_{t+1}^o\left(x_{t+1}, y_{t+1}\right)}{D_t^o\left(x_t, y_t\right)} \left[\frac{D_t^o\left(x_{t+1}, y_{t+1}\right)}{D_{t+1}^o\left(x_{t+1}, y_{t+1}\right)} \times \frac{D_t^o\left(x_t, y_t\right)}{D_{t+1}^o\left(x_t, y_t\right)} \right]^{1/2}$$
$$= \Delta TE_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right) \cdot \Delta TC_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right), \quad (4)$$

where $\Delta TE_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right)$ refers to technical efficiency change which measures the change in the output-orientated measure of Farrell technical efficiency between periods t and $t+1$ and $\Delta TC_o\left(x_{t+1}, y_{t+1}, x_t, y_t\right)$ refers to technical change which is the geometric mean of the shift in technology in time t and $t+1$ at input levels x_t and x_{t+1}.

The component distance functions in the above Malmquist TFP index decomposition can be measured using either nonparametric or parametric techniques. One main criticism of the Malmquist TFP index is that it is constructed under a constant returns to scale assumption of production technology. Hence, this Malmquist TFP index does not provide an accurate measure of productivity change because it ignores a measure of scale economies contribution. RAY and DESLI (1997), RAY (1998) and GRIFELL and LOVELL (1999) overcome this problem by developing a method using a nonparametric technique to decompose the Malmquist TFP index in which the contribution of scale economies is taken into account. The contribution of scale economies attributing to the Malmquist TFP growth can be measured using the ratios of distance function values corresponding to constant and variable returns to scale technologies. However, this framework can not be applied to a parametric technique because the constant returns to scale distance function measured by the parametric approach does not necessarily envelop the distance function with variable returns to scale leading to an inaccurate measure of the scale efficiency contribution. Subsequently, BALK (2001) extends the results obtained by RAY (1998) and derives the framework using a parametric technique to decompose the Malmquist TFP index into technical change, technical efficiency change, scale efficiency change and input- or output-mix effect. Although BALK'S approach is appealing, it does require the prior calculation of scale efficiency measures in which the scale effects are measured using the most productive scale size as a reference. As OREA (2002) pointed out, the scale efficiency measures are not bounded for either globally increasing, decreasing or constant returns to scale or for ray-homogenous technologies. More simply, in the case of single output, a U-shaped average cost curve is required for the most productive scale size to exist. Therefore, some practical problems may occur when adopting BALK'S approach. As this result, OREA (2002) presents an alternative approach using a parametric technique to decompose the Malmquist TFP index in which the contribution of scale economies is taken into account without requiring the prior calculation of scale efficiency measures. OREA applies DIEWERT'S (1976) Quadratic Identity Lemma to derive a generalized Malmquist TFP index decomposition which overcomes the practical problems of measuring the scale efficiency contribution shown in Balk. A parametric decomposition of a Generalized Malmquist TFP index presented in OREA (2002) is summarized in the following sections.

2.2 A Generalised Malmquist TFP Index Decomposition

Following OREA (2002), the logarithmic form of changes in output distance function between periods t and $t+1$ can be written as

$$\ln D_{t+1}^{o}\left(x_{t+1}, y_{t+1}\right) - \ln D_{t}^{o}\left(x_{t}, y_{t}\right) = \frac{1}{2}\sum_{m=1}^{M}\left[\varepsilon_{mt+1} + \varepsilon_{mt}\right]\cdot \ln\left(\frac{y_{mt+1}}{y_{mt}}\right) + \frac{1}{2}\sum_{k=1}^{K}\left[e_{mt+1} + e_{mt}\right]\cdot \ln\left(\frac{x_{kt+1}}{x_{kt}}\right) + \frac{1}{2}\left[\frac{\partial \ln D_{t+1}^{o}}{\partial t} + \frac{\partial \ln D_{t}^{o}}{\partial t}\right], \tag{5}$$

where $\varepsilon_{mt} = \partial \ln D_{t}^{o} / \partial \ln y_{m}$ represents the distance elasticities for the m-th output in period t and $e_{kt} = \partial \ln D_{t}^{o} / \partial \ln x_{kt}$ represents the distance elasticities for the k-th input in period t.

An output-oriented Malmquist TFP change index between periods t and $t+1$ is defined as the difference between aggregating the growth in outputs and inputs between periods t and $t+1$. By following DENNY, FUSS and WAVERMAN (1981), aggregating the growth in inputs is defined using distance elasticity shares rather than distance elasticities in order to satisfy all desirable properties of the TFP index[1]. The logarithmic form of a generalized output-oriented Malmquist TFP change index between periods t and $t+1$ can be written as

$$\ln m_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right) = \frac{1}{2}\sum_{m=1}^{M}\left[\varepsilon_{mt+1} + \varepsilon_{mt}\right]\cdot \ln\left(\frac{y_{mt+1}}{y_{mt}}\right) - \frac{1}{2}\sum_{k=1}^{K}\left[\left[s_{kt+1} + s_{kt}\right]\right]\cdot \ln\left(\frac{x_{kt+1}}{x_{kt}}\right), \tag{6}$$

where $s_{kt} = e_{kt} \Big/ \sum_{k=1}^{K} e_{kt}$ represents the distance elasticity share for the k-th input in period t.

Rearranging Equation (6), the logarithmic form of the generalized output-oriented Malmquist TFP change index can be decomposed as

$$\begin{aligned} \ln m_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right) &= \left[\ln D_{t+1}^{o} - \ln D_{t}^{o}\right] - \frac{1}{2}\left[\frac{\partial \ln D_{t+1}^{o}}{\partial t} + \frac{\partial \ln D_{t}^{o}}{\partial t}\right] \\ &+ \frac{1}{2}\sum_{k=1}^{K}\left[\left(-\sum_{k=1}^{K} e_{kt+1} - 1\right)\cdot s_{kt+1} + \left(-\sum_{k=1}^{K} e_{kt} - 1\right)\cdot s_{kt}\right]\cdot \ln\left(\frac{x_{kt+1}}{x_{kt}}\right) \\ &= \ln \Delta TE_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right) + \ln \Delta TC_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right) + \ln \Delta SCE_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right), \end{aligned} \tag{7}$$

where $\Delta TE_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right)$ represents the technical efficiency change which measures the change in the technical efficiency prediction of the *i*-th firm at the period t and period $t+1$, $\Delta TC_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right)$ represents the technical change which measures the mean of the technical change evaluated at the period t and period $t+1$ data points and $\Delta SCE_{o}\left(x_{t+1}, y_{t+1}, x_{t}, y_{t}\right)$ represents the scale efficiency change which measures the change in scale efficiency at the period t and period $t+1$ data. Equation (7) is expressed in terms of proportional rates of growth instead of a product of indices as in Equation (4). The $\ln m_{o}$ is viewed as the parametric counterpart of the Malmquist TFP index.

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1 Four desirable properties are identity, monotonicity, separability and proportionality.

2.3 Empirical framework to a parametric decomposition of a Generalised Malmquist TFP Index

The components of the generalised Malmquist TFP change index in Equation (7) can be measured by estimating a translog output distance function. For the case of M output and K inputs, a translog output distance function for a panel of $i = 1,...,I$ and $t = 1,...,T$ can be defined as follow

$$\begin{aligned} \ln D_{it}^{o}(x_t, y_t) = \beta_0 + \sum_{m=1}^{M} \beta_{y_m} \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \beta_{y_m y_n} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^{K} \beta_{x_k} \ln x_{kit} \\ + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{x_k x_l} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M} \beta_{x_k y_m} \ln x_{kit} \ln y_{mit} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 \\ + \sum_{k=1}^{K} \beta_{x_k t} \ln x_{kit} t + \sum_{m=1}^{M} \beta_{y_m t} \ln y_{mit} t, \end{aligned} \tag{8}$$

where β s are unknown parameters to be estimated. Young's theorem requires that the symmetry restriction is imposed so that $\beta_{x_k x_l} = \beta_{x_l x_k}$ and $\beta_{y_m y_n} = \beta_{y_n y_m}$. The additional restrictions required for homogeneity of degree +1 in outputs are $\sum_{m=1}^{M} \beta_{y_m} = 1$, $\sum_{n=1}^{M} \beta_{y_m y_n} = 0$ $(m = 1,...,M)$, $\sum_{m=1}^{M} \beta_{x_k y_m} = 0$ $(k = 1,...,K)$ and $\sum_{m=1}^{M} \beta_{y_m t} = 0$.

These restrictions can be imposed by estimating a model where the M-1 output quantities are normalized by the M-th output quantity. Equation (8) yields the estimating form of the output distance function, in which the distance term, D^o, can be viewed as an error term as follow

$$\begin{aligned} -\ln y_{Mit} = \beta_0 + \beta_{y_m} \sum_{m=1}^{M-1} \ln y_{mit}^{*} + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1} \beta_{y_m y_m} \ln y_{mit}^{*} \ln y_{mit}^{*} + \sum_{k=1}^{K} \beta_{x_k} \ln x_{kit} \\ + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{x_k x_l} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M-1} \beta_{x_k y_m} \ln x_{kit} \ln y_{mit}^{*} + \beta_z t + \frac{1}{2}\beta_{tt} t^2 \\ + \sum_{k=1}^{K} \beta_{x_k t} \ln x_{kit} t + \sum_{m=1}^{M-1} \beta_{y_m t} \ln y_{mit}^{*} t - \ln D_{it}^{o}, \end{aligned} \tag{9}$$

where $y_{mit}^{*} = (y_{mit} / y_{Mit})$ and $-\ln D_{it}^{o} = v_{it} - u_{it}$. By replacing the distance term, $-\ln D_{it}^{o}$, with a composed error term, $v_{it} - u_{it}$, Equation (9) can be estimated as a standard stochastic frontier production function where v_{it} s are the random errors, assumed to be i.i.d. and have $N(0,\sigma_v^2)$ - distribution, independent of the u_{it}, the technical inefficiency effects. The u s are assumed to be i.i.d. normal random variable, $u \sim \left|N(0,\sigma_u^2)\right|$.

Given the distributional assumptions of the random variables defined in the above, the unknown parameters in Equation (9) are estimated using the method of maximum likelihood (ML). BATTESE and CORRA (1977) suggested that the two variance parameters can be replaced by the two new parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$. The γ-parameterization has advantages in seeking to obtain ML estimates because the parameter space for γ can be searched for a suitable starting value for the iterative maximization routine. The unknown parameters are obtained by using the computer program, FRONTIER 4.1 (COELLI, 1996a).

The components of the Malmquist TFP change index presented in Equation (7) can be computed after estimating the output distance function in Equation (9). The technical efficiency change can be calculated by

$$\ln \Delta TE_o = \ln\left(\frac{TE_{it+1}}{TE_{it}}\right) = \ln\left(\frac{E(\exp(-u_{it+1})|(v_{it+1} - u_{it+1}))}{E(\exp(-u_{it})|(v_{it} - u_{it}))}\right), \tag{10}$$

where TE_{it} represents the technical efficiency prediction of the i-th firm in the t-th time period. The other components of the Malmquist TFP change index can be written in terms of the parameter estimates of the output distance function in Equation (5). The technical change yields

$$\ln \Delta TC_o = -\frac{1}{2}\left[2(\beta_t + \beta_{tt}(t + 1/2)) + \sum_{k=1}^{K} \beta_{x_k t}(\ln x_{kit+1} + \ln x_{kit}) + \sum_{m=1}^{M-1} \beta_{y_m t}(\ln y^*_{mit+1} + \ln y^*_{mit})\right]. \tag{11}$$

The scale efficiency change in terms of the parameter estimates of the output distance function yields

$$\ln \Delta SEC_o = \frac{1}{2}\sum_{k=1}^{K}\left[\left(-\sum_{k=1}^{K} e_{kit+1} - 1\right)\cdot s_{kit+1} + \left(-\sum_{k=1}^{K} e_{kit} - 1\right)\cdot s_{kit}\right]\cdot \ln\left(\frac{x_{kit+1}}{x_{kit}}\right), \tag{12}$$

where $e_{kit} = \partial \ln D_t^o / \partial \ln x_{kit} = \beta_{x_k} + \sum_{k=1}^{K} \beta_{x_{kk}} \ln x_{kit} + \sum_{m=1}^{M-1} \beta_{x_k y_m} \ln y^*_{kit} + \beta_{x_k t} t_{it}$ and $s_{kit} = e_{kit} \Big/ \sum_{k=1}^{K} e_{kit}$.

3 DATA DISCUSSIONS

A data set used in this study is adjusted for quality which measures agricultural outputs and inputs. Data on 46 countries over the time period of 1992 through 2002 are used in the empirical analysis. Countries are divided into three categories, using the following definitions. The first category called "EU 15" countries consists of countries which founded the EU and countries which joined the EU before 1996. We also include Norway and Switzerland into this group. The second category called "EU 10" countries consists of countries which joined the EU in 2004. The last category called "Transition" countries consists of all transition countries after the breakdown of the former Soviet Union as well as Turkey. A list of the countries in each group is summarised in Table 1.

Table 1: Classification of selected countries

Group	Country
EU15*	Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK
EU10**	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
Transition	Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Georgia, Kazakhstan, Kyrgyzstan, Macedonia, Moldova Republic, Romania, Russian Federation, Serbia-Montenegro, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan

Notes: * Countries joined the EU before January, 1995 including Norway and Switzerland;
** Countries joined the EU in May, 2004.

The primary source of data is obtained from the website of the FAO of United Nations and, in particular, the agricultural statistics provided by the AGROSTAT system, supported by the Statistics

Division of the FAO. The FAO dataset used in this study has been used in many studies about agricultural productivity. The data used to measure the TFP decomposition contain the measurements of agricultural output and input quantities. In this study, the production technology is presented by two output variables (i.e., crop and livestock) and five input variables (i.e., land, tractor, labour, fertilizer and livestock). The definitions of these variables are summarised as follow:

The output series for the two output variables are derived by aggregating detailed output quantity data on 127 agricultural commodities (115 crop commodities of average 1999-2001 and 12 livestock commodities), which are produced in the studied countries. Construction of output data series uses the following steps. First, average aggregate for the base period 1999 to 2001 are calculated. These aggregates are constructed using output quantity data and international average prices (expressed in US dollars) derived using the Geary-Khamis method. The next step is to extend the average base period output series 1999 to 2001 to cover the whole study period 1992-2002. This is achieved using the FAO production index number series for crops and livestock separately.

Given the constraints on the number of input variables that could be used in the analysis, only five input variables are considered to be used in the study. Definitions of these input variables are defined as follow. Land input variable represents the arable land, land under permanent crops as well as the area under permanent pasture in hectares. Tractor input variable represents the total number of wheel and crawler tractors, but excluding garden tractors, used in agriculture. Labour input variable refers to economically-active population in agriculture. Following other studies (HAYAMI and RUTTAN, 1970; FULGINITI and PERRIN, 1997) on inter-country comparison of agricultural productivity, fertilizer input variable represents the sum, in nutrient-equivalent terms, the commercial use of nitrogen, potassium, and phosphate expressed in thousands of metric tons. Livestock input variable used in the study is the sheep-equivalent of the five categories of animals used in constructing this variable. The categories considered are: Buffaloes, cattle, pigs, sheep and goats. Numbers of these animals are converted into sheep-equivalents using conversion factors: 8.0 for buffalos and cattle; and 1.00 for sheep, goats and pigs.

Descriptive statistics of the variables used in the study are presented in Table 2. There are large variations observed in output and input variables across countries.

Table 2: Data overview for 46 selected countries, 1992 to 2002

	Variables	Units	Average	Min	Max	S.D.
Input	Land	$\times 10^3$ hectares	18,005	9,000	221,747	43,481
	Machinery	tractors	275,217	450	1,660,000	395,242
	Fertiliser	metric tons	603,607	700	5,510,000	946,751
	Labour	$\times 10^3$ persons	1,236	2	14,697	2,461
	Livestock	$\times 10^3$ heads	50,223	330	593,697	75,742
Output	Crop value	$\times 10^3$ dollars	3,436,528	15,710	21,851,139	5,011,663
	Livestock value	$\times 10^3$ dollars	3,244,477	30,000	26,888,503	4,543,331

4 Results

Prior to estimation, all variables are scaled to have unit means. This transformation does not alter the performance measures obtained, but does allow one to interpret the estimated first-order coefficients of the translog output distance function as elasticities of distance with respect to inputs and outputs evaluated at the sample means. Livestock output is used as the normalising output (see Equation 9). The translog output distance function is estimated using the approach described in Section 2.3. Hypothesis tests regarding the structure of the production technology such as the presences of technical inefficiency and technical change are conducted using the likelihood ratio tests. All null hypotheses are rejected which imply the existences of technical inefficiency and technical change in the model.

We began by estimating the translog output distance function in Equation (9) using the method of ML. The set of ML estimates is presented in Table 3.

Table 3: Estimated parameters of the Output Distance Model[a]

Parameter	Estimates	*t*-Statistic	Parameter	Estimates	*t*-Statistic
β_0	0.3694	-0.1225	β_{x2x5}	8.4473	-1.9714
β_{y1}	0.2986	0.0760	β_{x3x4}	12.7308	1.7289
β_{y1y1}	0.8281	-0.0860	β_{x3x5}	9.4575	-1.2925
β_{x1}	-0.1175	-0.1442	β_{x4x5}	-5.2767	-2.0204
β_{x2}	-0.1945	-0.1999	β_{x1y1}	-9.2042	-3.5792
β_{x3}	-0.2154	-0.1379	β_{x2y1}	-8.3084	-3.7666
β_{x4}	-0.0259	-0.1351	β_{x3y1}	-1.0267	-3.7880
β_{x5}	-0.4675	-0.1762	β_{x4y1}	-10.9166	-3.1119
β_{x1x1}	0.0936	0.5039	β_{x5y1}	2.1319	5.6849
β_{x2x2}	0.0010	-0.0257	β_t	0.0288	-8.2120
β_{x3x3}	-0.1328	0.0023	β_{tt}	-5.0181	1.0809
β_{x4x4}	0.3414	-0.1789	β_{x1t}	6.8838	-3.7616
β_{x5x5}	0.4778	-0.0121	β_{x2t}	4.1586	-0.2991
β_{x1x2}	-0.0455	0.0424	β_{x3t}	-1.3196	0.8754
β_{x1x3}	0.0943	0.1328	β_{x4t}	3.0327	2.5739
β_{x1x4}	-0.1264	0.0995	β_{x5t}	-3.7959	1.2228
β_{x1x5}	-0.0897	-0.0599	β_{y1t}	-1.4725	-0.9429
β_{x2x3}	0.1276	0.0754	σ^2	7.1548	5.6135
β_{x2x4}	-0.0554	0.7186	γ	-1.8007	5.7077

Notes: [a] Subscripts on β_x coefficients refer to inputs: 1 = land; 2 = tractors; 3 = fertilizer; 4 = labour; 5 = livestock input and subscripts on β_y coefficients refer to outputs: 1 = crops; 2 = livestock output.

All the first-order coefficients have the expected signs, implying that the output distance functions are increasing in outputs and decreasing in inputs at the sample mean. The estimate of the output elasticities is 0.2986 and 0.7014 for crops and livestock, respectively. The estimates of the input elasticities are –0.1175, –0.1945, –0.2154, –0.0259 and –0.4675 for land, tractors, fertilizer, labour, and livestock, respectively. The sum of the input elasticities provides information on scale economies. The sum of these input elasticities is –1.0208, indicating that the technology exhibits moderately increasing returns to scale at the sample mean. The first-order coefficients of the time trend variable in Table 3 provide estimates of the average annual rate in technical change. The output distance function estimates suggest that the technology is improving at a rate of 2.57 % per annum. Following the estimation, tests of the regularity conditions are checked at each data point in the sample of 506 observations. We find that the convexity condition and the monotonicity constraints in outputs are satisfied at all observations in the output distance function. The monotonicity constraints in inputs are violated at 12, 0, 2, 14, and 0 percent of all observations in the case of land, tractors, fertilisers, labour and livestock inputs, respectively. Then, the parameter estimates presented in Table 3 are used to calculate the components of the Malmquist TFP growth decomposition.

Table 4 on the next page presents unweighted average values of technical efficiency scores and the components of the Malmquist TFP growth for the 46 countries over the period 1992 to 2002. We begin by discussing the results of technical efficiency scores, followed by the results of the Malmquist TFP growth decomposition. Estimated technical efficiency scores for each firm in the sample are presented in the third column of Table 4. Technical efficiency scores range from 0.582 by Belarus to maximum 0.933 by Bulgaria with an unweighted average of 0.818. The average technical efficiency score implies that the countries in this study were, on average, producing 81.8 percent of the outputs that could be potentially produced using the observed input quantities.

Some transition counties such as Hungary, Bulgaria and Moldova Republic exhibited quite impressive technical efficiency scores over the sample period. If the high efficiency scores for Hungary are less surprisingly, so, need high performance levels for Bulgaria and Moldova a special statement. According to the Government's figures, Bulgaria's agriculture currently generates about 12 percent of gross domestic product and provides a livelihood for about 368,000 people and a subsidiary source of income for almost one million people. The Bulgarian agricultural sector has been highly subsided by Government unlike other transition countries. The subsidies were not covered by this analysis and this could lead to the overestimation of its technical efficiency scores. Moldova Republic showed a significant increase of technical efficiency scores after the year 1997. An increase in technical efficiency scores could be explained by a decrease in its uses of fertilizers and plant-protection agents. The new ownership conditions and the fragmentation of plots do not permit farmers to undertake the necessary expenditures. Ninety-nine percent of the crops were produced without the use of fertilizers or plant-protection agents. Therefore, yields were highly depended on the natural conditions.

Belarus has the lowest technical efficiency scores over all observation period and show in average only 0,582. It indicates that using available inputs Byelorussian agriculture can potentially increase the output on 42 per cent. The low technical efficiency in Byelorussian agriculture could be explained by the very low-priced energy deliveries from Russia and state controlled economy. The Byelorussian economy remains about 80 per cent state-controlled, as it has been since Soviet times. However, the country has arguably handled the difficult transition since the collapse of the Soviet Union better than most of its peers. The country is relatively stable, economically, but depends to a large extent on raw material supplies from its close ally Russia. Agriculture remains largely in state hands and is dominated by collective farming. Belarus is therefore one of the very few state-capitalistic national economies remaining.

Average country technical efficiency scores by the group of the countries indicate that average country technical efficiency scores is 0.853 by the EU 15 countries, 0.844 by the EU 10 countries and 0.777 by the transition countries group. Average country technical efficiency scores of the transition countries were lower than those of the EU 10 and 15 countries, respectively, in every single period. In the same time the divergences between new and old members of the European Union became less obviously only approximately 1 per cent. Thus, these results corroborate with other productivity measurements across European agricultural sectors using non-parametric Malmquist Index (LISSITSA et al., 2006)

The components of the Malmquist TFP growth decomposition are calculated from the parameter estimates presented in Table 3. The Malmquist TFP growth can be decomposed into technical efficiency change (TECH), technical change (TCH) and scale efficiency change (SECH) effects. The Malmquist TFP growth ranges from –0.49 percent by Ireland to 6.43 percent by Tajikistan with an unweighted average of 2.28 percent. Two countries such as Ireland and Turkey which exhibited TFP regress over the sample periods. TFP regress for Ireland was driven by deterioration in both technical and scale efficiencies whereas TFP regress for Turkey was due to technological regress and deterioration in scale efficiency. The technical efficiency change ranges from –2.67 percent by Turkmenistan to 3.97 percent by Tajikistan with an unweighted average of –0.14 percent. Twenty-four countries showed deterioration in technical efficiency change. Of these countries, nine countries are within the EU 15 countries; six countries are within the EU 10 countries and nine countries are within the transition countries. A significant deterioration in technical efficiency change in the republics of former Yugoslavia or in some countries of former Soviet Union could be simply explained by civil war and a political instability during the study periods. A deterioration in technical efficiency change in some countries within the EU 15 countries such as Ireland, UK, Finland and Norway in our opinion, are astonishing. However, they correspondent also with results of other similar studies (SERRAO, 2003). The negative technical efficiency change in these countries, perhaps, is correlated with BSE and FMD crises in the European Union as well as with price fluctuations on the beef and pork markets.

A significant acceleration in technical efficiency change in Post-Socialistic republics like Tajikistan, Albania and Moldova Republic could be explained by a drastic reduction of the variable inputs use like fertilizers, machinery and livestock numbers. The technical change ranges from –0.21 percent by Turkey to 6.95 percent by Kazakhstan with an unweighted average of 2.57 percent. All countries except Turkey indicated technological progress. Many countries within the EU 10 and transition countries showed significant technological progress over the time periods. The scale efficiency change ranges from –1.97 percent by Kazakhstan to 0.84 percent by Belarus with an unweighted average of –0.15 percent. Twenty-five countries showed deterioration in scale efficiency change. Of these countries, six countries are within the EU 15 countries; five countries are within the EU 10 countries and fourteen countries are within the transition countries.

Table 4: Unweighted average values of Technical Efficiency Scores and TFP growth by each country

Country	Region	TE	Average Value in Percentage			
			TECH	TCH	SECH	TFP Change
Austria	EU15	0.859	0.01	2.54	-0.15	2.40
Bel-Lux	EU15	0.842	0.17	1.31	0.13	1.61
Denmark	EU15	0.922	0.29	2.12	0.20	2.61
Finland	EU15	0.884	-0.62	2.65	0.00	2.04
France	EU15	0.836	0.16	1.43	0.00	1.60
Germany	EU15	0.893	0.29	0.56	0.13	0.98
Greece	EU15	0.902	-0.39	3.26	-0.27	2.59
Ireland	EU15	0.810	-1.32	1.04	-0.22	-0.49
Italy	EU15	0.855	-0.20	1.25	-0.07	0.98
Netherlands	EU15	0.903	0.24	0.31	0.35	0.91
Norway	EU15	0.781	-1.00	1.50	0.09	0.58
Portugal	EU15	0.751	-0.68	1.49	-0.01	0.81
Spain	EU15	0.827	-0.89	2.22	0.11	1.44
Sweden	EU15	0.870	-0.36	2.90	-0.02	2.52
Switzerland	EU15	0.897	0.06	1.66	0.12	1.83
UK	EU15	0.811	-0.56	1.43	0.12	0.98
Cyprus	EU10	0.786	-1.19	2.79	-0.14	1.46
Czech Rep	EU10	0.855	-0.37	1.57	0.13	1.32
Estonia	EU10	0.842	1.95	4.31	-0.93	5.33
Hungary	EU10	0.929	-0.59	2.79	0.01	2.21
Latvia	EU10	0.801	0.72	4.28	-0.56	4.44
Lithuania	EU10	0.802	-0.83	3.42	-0.13	2.45
Malta	EU10	0.884	-0.50	3.75	0.03	3.28
Poland	EU10	0.834	0.46	0.11	0.04	0.60
Slovakia	EU10	0.899	-0.38	2.34	0.12	2.08
Slovenia	EU10	0.808	1.09	3.75	-0.61	4.23
Albania	Trans	0.862	0.86	0.55	-0.75	0.65
Armenia	Trans	0.781	-1.12	3.83	-0.17	2.55
Azerbaijan	Trans	0.670	-0.93	2.42	-0.10	1.39
Belarus	Trans	0.582	0.83	1.49	0.84	3.17
Bosnia Herzg	Trans	0.678	-0.58	5.18	-1.11	3.49
Bulgaria	Trans	0.933	0.12	3.80	-0.20	3.71
Croatia	Trans	0.842	0.51	3.73	0.11	4.35
Georgia	Trans	0.786	-1.38	2.82	-0.26	1.18
Kazakhstan	Trans	0.847	0.10	6.95	-1.97	5.08
Kyrgyzstan	Trans	0.871	-0.16	4.67	-0.11	4.40
Macedonia	Trans	0.607	-1.79	4.60	0.12	2.93
Moldova Rep	Trans	0.906	0.81	3.39	-0.98	3.22
Romania	Trans	0.866	0.09	1.77	0.03	1.89
Russian Fed	Trans	0.834	0.01	1.81	0.30	2.12
Serbia-Monte	Trans	0.820	-0.44	1.95	-0.17	1.34
Tajikistan	Trans	0.679	3.97	3.43	-0.96	6.43
Turkey	Trans	0.827	0.06	-0.21	-0.01	-0.17
Turkmenistan	Trans	0.641	-2.67	6.37	-0.20	3.50
Ukraine	Trans	0.818	0.25	1.28	0.30	1.83
Uzbekistan	Trans	0.687	-1.03	2.16	-0.03	1.10
Mean	EU15	0.853	-0.28	1.68	0.05	1.45
Mean	EU10	0.844	0.04	2.91	-0.21	2.74
Mean	Trans	0.777	-0.12	3.10	-0.27	2.71
Mean	ALL	0.818	-0.14	2.57	-0.14	2.28

Table 5 presents weighted growth rate of the TFP growth decomposition and its components by the group of the countries over the period 1992 to 2002. Examining the growth rate by the group of countries will allow us to explain agricultural productivity trends in the European countries and to answer the question we raised earlier that how far agricultural productivity of the transition countries are from the economic standards in the EU countries. TFP growth by all countries increases by 16.80 percent over the sample period with a weighted average of about 1.527 percent per annum. Overall, technical change and scale efficiency change increase by 16.46 and 0.59 percent over the sample period for a weighted average of about 1.496 and 0.054 percent per annum, respectively, whereas technical efficiency change decreases by 0.3 percent over the sample period with a weighted average of about –0.027 percent per annum. The EU 15 countries indicated the TFP growth increases by 14.21 percent over the sample period with a weighted average of about 1.292 percent per annum. Technical change and scale efficiency change increase by 14.90 and 0.66 percent over the period 1992 to 2002 for a weighted average of about 1.355 and 0.060 percent per annum, respectively, whereas scale efficiency change decreases by 1.26 percent over the sample period with a weighted average of about –0.114 percent per annum.

Table 5: Weighted growth rates of the Malmquist TFP growth decomposition by group of the countries (in percentage)

Period	Region	Efficiency change	Technical change	Scale efficiency change	TFP change
1992-1994	EU15	-0.793	1.440	-0.001	0.612
1994-1996	EU15	-0.181	1.164	0.043	1.020
1996-1998	EU15	0.074	0.931	0.033	1.042
1998-2000	EU15	0.310	0.690	0.099	1.109
2000-2002	EU15	0.180	0.479	0.046	0.708
1992-2002	**EU15**	**-0.114**	**1.355**	**0.060**	**1.292**
1992-1994	EU10	-0.883	1.216	0.014	0.315
1994-1996	EU10	0.636	1.171	-0.032	1.796
1996-1998	EU10	0.315	0.916	-0.015	1.224
1998-2000	EU10	0.151	0.659	0.056	0.870
2000-2002	EU10	0.226	0.431	-0.028	0.632
1992-2002	**EU10**	**0.117**	**1.261**	**-0.002**	**1.392**
1992-1994	Trans	-0.142	1.496	0.260	1.619
1994-1996	Trans	-0.384	1.374	0.009	0.983
1996-1998	Trans	-0.003	1.233	0.008	1.238
1998-2000	Trans	0.407	1.058	-0.122	1.350
2000-2002	Trans	0.279	0.895	0.021	1.204
1992-2002	**Trans**	**0.041**	**1.775**	**0.048**	**1.882**
1992-1994	All	-0.531	1.440	0.106	0.996
1994-1996	All	-0.176	1.243	0.024	1.086
1996-1998	All	0.065	1.037	0.019	1.124
1998-2000	All	0.329	0.815	0.018	1.171
2000-2002	All	0.220	0.627	0.030	0.882
1992-2002	**All**	**-0.027**	**1.496**	**0.054**	**1.527**

There were deceleration in technical efficiency change during the periods 1992 to 1996 and deceleration in scale efficiency change during the periods 1992 to 1994. The TFP growth by the EU 15 countries was low during the periods 1992 to 1994 and 2000 to 2002. The EU 10 countries indicated the TFP growth increases by 15.31 percent over the sample period with a weighted average of about 1.392 percent per annum. Technical efficiency change and technical change increase by 1.28 and 13.87 percent over the sample period for a weighted average of about 0.117 and 1.261 percent per annum, respectively, whereas scale efficiency change decreases by 0.02 percent over the sample period with a weighted average of about –0.002 percent per annum. There were deceleration in technical efficiency change during the periods 1992 to 1994 and deceleration in scale efficiency change during the periods 1994 to 1998 and 2000 to 2002. The TFP growth by the EU 10 countries was low during the periods 1998 to 2002. The transition countries indicated the TFP growth increases by 20.70 percent over the sample period with a weighted average of about 1.882 percent per annum. Technical efficiency change, technical change and scale efficiency change increase by 0.45, 19.53 and 0.53 percent over the sample period for a weighted average of about 0.041, 1.775 and 0.048 percent per annum, respectively. There were slowdown in technical efficiency change during the periods 1992 to 1998 and deceleration in scale efficiency change during the periods 1998 to 2000. The TFP growth by the transition countries was low during the periods 1994 to 1996. TFP growth for each group of countries was mainly driven by technology progress. The results indicate deterioration in technical efficiency by the EU 15 countries but acceleration in technical efficiency by the EU 10 and transition countries. This result implies that the EU 10 and transition countries increased the outputs by improving technical efficiency more than the EU 15 countries group. Technological progress by the transition countries was higher than the EU 15 countries and EU 10 countries, respectively. The results show deterioration in scale efficiency by the EU 10 countries but acceleration in scale efficiency by the EU 15 and transition countries.

The achieved results confirm the previous productivity analysis using non-parametric approach (LISSITSA et al., 2006), which shown that new members of the European Union and all other transition countries had higher TFP indexes then EU 15 countries. That means that the agricultural sectors of transition countries are becoming more competitive compared to the "old" European Union.

5 SUMMARY AND CONCLUSIONS

This study employs a parametric decomposition of a Generalized Malmquist TFP index to measure agricultural productivity in European countries. The Generalized Malmquist TFP index can be decomposed into technological change, technical efficiency change and scale efficiency change. This study is empirically implemented by using a panel data set of the European agriculture on 46 countries over the time period of 1992-2002 to measure and compare agricultural productivity in the transition countries with those of the EU countries.

The empirical findings indicate that the weighted average TFP growth in the European agriculture over the study period grew at 1.527 percent per annum which was driven by –0.027 percent in technical efficiency change, 1.496 percent in technical change and 0.054 percent in scale efficiency change. Turning to the performance of the different groups of countries, the EU 15 countries operated at higher technical efficiency levels than the EU 10 and transition countries over the study periods. The weighted average TFP growth grew at 1.292 percent per annum for the EU 15 countries, 1.392 percent per annum for the EU 10 countries and 1.882 percent per annum for the transition countries. TFP growth for each group of countries was mainly driven by the technology progress. The results also show that the EU 10 and transition countries increased the outputs by improving technical efficiency more than those located within the EU 15 countries. Transition countries indicated impressive "catch-up" effect comparing with the EU 15 and 10 countries.

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