Agricultural Productivity Growth in the European Union and Transition Countries

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Abstract

Economic reform in the Central and Eastern European countries in the 1980s helped transform the structure and volume of agricultural production, consumption and trade, and resulted in significant agricultural productivity improvements. However, there are large differences among the transition countries in the magnitude and direction of these changes. The main objective of this study is to measure and compare the levels and trends in agricultural productivity in transition countries with those of the European Union (EU) countries making use of the most recent data available from the Food and Agriculture Organization (FAO). This study employs a parametric distance function approach to measure Malmquist productivity index as well as the magnitude and direction of technical change. The Malmquist productivity index is decomposed into technical change (TC), technical efficiency change (TEC) and scale efficiency change (SEC) in which TC is decomposed into input- and output- biased TC. These measures provide insightful information for researchers in designing policies to achieve a high growth rate in transition countries.

Key words: agriculture, parametric, productivity, transition countries, biased technical change

1. Introduction

The Central and Eastern European Countries (CEECs) and Newly Independent States (NIS) of the former Soviet Union began major market-oriented reform of their planned economies in the late 1980s and early 1990s. Economic reforms transformed the structure and volume of these countries' agricultural production, consumption and trade and introduced important agricultural productivity changes. The World Bank analysis (2005) remains the very large gap between global agricultural development and the performance of the transition countries but also indicates a further differentiation between CEE and NIS countries in the pace of agricultural reform. Given these developments and divergences researcher and analysts are increasingly seeking to answer questions like: How large are differences amongst the agricultural sectors concerning their performance? Has the EU enlargement caused a catching-up effect (or positive technical progress)? Is the productivity change in most countries biased by decreased using of production inputs? Many similar questions can be raised. However, the core question is now: how far are agricultural sectors of transition countries from European standards in terms of their economic performance and how much time do they need to archive the same level of total factor productivity? In approaching these questions, divergences among several groups of transition countries are important.

The main purpose of this paper is to measure TFP developments in agriculture of transition countries after breakdown of socialism and 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 (MPI) presented in Caves et al. (1982) and Färe et al. (1994). This MPI became common in practice by applying both nonparametric and parametric techniques to measure productivity growth. In this study, we employ a parametric distance function approach to decompose the MPI into technical change (TC), technical efficiency change (TEC) and scale efficiency change (SEC). We measure the magnitude of TC and also the direction of TC. Understanding the magnitude and direction of TC provide insightful information for researchers in designing policies to achieve a high growth rate in transition countries. The concept of measuring the direction of TC was originated by Hicks (1963). Previous studies focused on the relative measures of input-biased TC with respect to each individual input. Färe et al (1997) proposed a method to analyze the sources of TC from both input and output sides. The TC derived from the MPI can be decomposed into input- and output- TC and Hick neutral TC. We extend our parametric distance function approach to measure the effects on the input- and output- biased TCs from the MPI. 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 organized as follows. Section 2 presents the MPI decomposition, followed by a discussion of the methodologies to measure the MPI decomposition. Section 3 discusses the data set and the definitions of all variables. Empirical results are presented and discussed in Section 4 and then conclusions follow in the final section.

2. Methodology

2.1 The MPI Decomposition

The MPI presented in Caves et al. (1982) and Färe et al. (1994) is defined using distance function[1]. The output distance function is defined as

$$D_t^o(x_t, y_t) = \min\{\theta : (x_t, y_t/\theta) \in S_t\}, \tag{1}$$

where S_t is the production technology which transforms inputs $x_t \in R_+^K$ into net outputs $y_t \in R_+^M$ for each time period $t = 1,...,T$. $D_t^o(x_t, y_t) \le 1$ if and only if $(x_t, y_t) \in S_t$.

Following Färe et al (1994), the output-orientated MPI can be decomposed into TEC $\left(\Delta TE_o^{crs}\right)$ and TC $\left(\Delta TC_o^{crs}\right)$

$$\begin{aligned} m_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t) &= \frac{D_{t+1}^o(x_{t+1}, y_{t+1})}{D_t^o(x_t, y_t)} \left[\frac{D_t^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_{t+1}, y_{t+1})} \times \frac{D_t^o(x_t, y_t)}{D_{t+1}^o(x_t, y_t)} \right]^{1/2} \\ &= \Delta TE_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t) \cdot \Delta TC_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t). \end{aligned} \tag{2}$$

Further, Färe et al (1997) extends equation (2) and shows that the TC can be decomposed into the magnitude of TC $\left(\Delta M_o^{crs}\right)$ and a bias index of TC $\left(\Delta B_o^{crs}\right)$, while the ΔB_o^{crs} can be decomposed into output-biased TC $\left(OB\Delta T_o^{crs}\right)$ and input-biased TC $\left(IB\Delta T_o^{crs}\right)$

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

$$\Delta TC_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_t^o(x_t, y_t)}{D_{t+1}^o(x_t, y_t)} \left[\frac{D_{t+1}^o(x_t, y_t)}{D_t^o(x_t, y_t)} \times \frac{D_t^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_{t+1}, y_{t+1})} \right]^{1/2} \tag{3}$$
$$= \Delta M_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t) \cdot \Delta B_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t),$$

where

$$\Delta B_o^{crs}(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D_{t+1}^o(x_{t+1}, y_t)}{D_t^o(x_{t+1}, y_t)} \times \frac{D_t^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_{t+1}, y_{t+1})} \right]^{1/2} \cdot \left[\frac{D_{t+1}^o(x_t, y_{t+1})}{D_t^o(x_t, y_t)} \times \frac{D_t^o(x_{t+1}, y_t)}{D_{t+1}^o(x_{t+1}, y_t)} \right]^{1/2} \tag{4}$$
$$= OB\Delta T_o^{crs}(x_{t+1}, y_{t+1}, y_t) \cdot IB\Delta T_o^{crs}(x_t, y_t, x_{t+1}).$$

If $OB\Delta T_o^{crs}$ and $IB\Delta T_o^{crs}$ are simultaneously equal to one, the ΔM_o^{crs} equals the TC under joint Hicks neutrality.

The component distance functions in MPI decomposition can be measured using either nonparametric or parametric techniques. One main criticism of the MPI is that it is constructed under constant returns to scale (CRS) assumption of production technology. Therefore, it does not provide an accurate measure of productivity change because it ignores a measure of scale economies. Ray and Desli (1997) and Grifell and Lovell (1999) develop a method using a nonparametric technique to decompose the MPI in which the contribution of scale economies is taken into account. The contribution of scale economies can be measured using the ratios of distance function values corresponding to CRS and variable returns to scale (VRS) technologies. However, this framework can not be applied to a parametric technique because the CRS distance function measured by the parametric approach does not necessary envelop the distance function with VRS leading to an inaccurate measure of the SE contribution. Subsequently, Balk (2001) extends the results obtained by Ray (1998) and derives the framework using a parametric technique to decompose the MPI into TC, TEC, SEC and input- or output-mixed effect. Although Balk's approach is appealing, it does require the prior calculation of SE measures in which the scale effects are measured using the most productive scale size as a reference. As Orea (2002) pointed out, the SE measures are not bounded for either globally increasing, decreasing or CRS or for ray-homogenous technologies. 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 MPI in which the contribution of scale economies is taken into account without requiring the prior calculation of SE measures.

2.2 A Generalized MPI Decomposition

Orea (2002) applies Diewert's (1976) Quadratic Identity Lemma to derive a generalized MPI decomposition. The logarithmic form of a generalized output-oriented Malmquist TFP change index between periods t and $t+1$ can be written as[2]

$$\begin{aligned} \ln m_o^{vrs}(x_{t+1}, y_{t+1}, x_t, y_t) &= \left[\ln D_{t+1}^o - \ln D_t^o\right] - \frac{1}{2}\left[\frac{\partial \ln D_{t+1}^o}{\partial t} + \frac{\partial \ln D_t^o}{\partial t}\right] \\ &+ \frac{1}{2}\sum_{k=1}^{K}\left[\left(-\sum_{k=1}^{K} e_{kt+1} - 1\right)\cdot s_{kt+1} + \left(-\sum_{k=1}^{K} e_{kt} - 1\right)\cdot s_{kt}\right]\cdot \ln\left(\frac{x_{kt+1}}{x_{kt}}\right) \qquad (5) \\ &= \ln \Delta TE_o^{vrs}(x_{t+1}, y_{t+1}, x_t, y_t) + \ln \Delta TC_o^{vrs}(x_{t+1}, y_{t+1}, x_t, y_t) + \ln \Delta SCE_o^{vrs}(x_{t+1}, y_{t+1}, x_t, y_t), \end{aligned}$$

where $e_{kt} = \partial \ln D_t^o \big/ \partial \ln x_{kt}$ and $s_{kt} = e_{kt} \Big/ \sum_{k=1}^{K} e_{kt}$ represent the distance elasticity and distance elasticity share for the k-th input in period t, respectively. ΔTE_o^{vrs} represents the TEC, ΔTC_o^{vrs} represents the TC and ΔSCE_o^{vrs} represents the SEC. Equation (5) is expressed in terms of proportional rates of growth instead of a product of indices as in equation (2). The $\ln m_o^{vrs}$ is viewed as the parametric counterpart of the MPI.

2.3 Empirical Framework to a Parametric Decomposition of a Generalized MPI

[2] When information on output and input prices is available, one can also calculate an allocative efficiency change component, which is equal to the difference between a Törnqvist TFP index and the MPI obtained from the output distance frontier in equation (11). Therefore, the TFP growth can be decomposed into TC, TEC, SEC and input- or output- mix allocative efficiency effects like Balk's decomposition.

The components of the generalized MPI can be measured by estimating a translog output distance function. The estimating form of the translog output distance function can be defined as[3]

$$
\begin{aligned}
-\ln y_{Mit} &= \beta_0 + \beta_{y_m} \sum_{m=1}^{M-1} \ln y_{mit}^* + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{n=1}^{M-1} \beta_{y_m y_m} \ln y_{mit}^* \ln y_{mit}^* + \sum_{k=1}^{K} \beta_{x_k} \ln x_{kit} \\
&+ \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{x_k x_l} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K} \sum_{m=1}^{M-1} \beta_{x_k y_m} \ln x_{kit} \ln y_{mit}^* + \beta_z t + \frac{1}{2} \beta_{tt} t^2 \\
&+ \sum_{k=1}^{K} \beta_{x_k t} \ln x_{kit} t + \sum_{m=1}^{M-1} \beta_{y_m t} \ln y_{mit}^* t - \ln D_{it}^o,
\end{aligned}
\tag{6}
$$

where βs are unknown parameters to be estimated, $y_{mit}^* = \left(y_{mit} / y_{Mit} \right)$ 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 (6) can be estimated as a standard stochastic frontier production function where v_{it} s are the random errors, and u s are non-negative random variable.

The unknown parameters are estimated using the method of maximum likelihood (ML)[4]. The components of the MPI decomposition can be computed after estimating the output distance function. The TEC can be calculated by

$$
\ln \Delta TE_o^{vrs} = \ln \left(\frac{TE_{it+1}}{TE_{it}} \right) = \ln \left(\frac{E\left(\exp(-u_{it+1}) \middle| (v_{it+1} - u_{it+1}) \right)}{E\left(\exp(-u_{it}) \middle| (v_{it} - u_{it}) \right)} \right), \tag{7}
$$

where TE_{it} represents the TE prediction of the *i*-th firm in the *t*-th time period. The other components of the Malmquist TFP change yield

$$
\ln \Delta TC_o^{vrs} = -\frac{1}{2} \left[2\left(\beta_t + \beta_{tt} (t + 1/2) \right) + \sum_{k=1}^{K} \beta_{x_k t} \left(\ln x_{kit+1} + \ln x_{kit} \right) + \sum_{m=1}^{M-1} \beta_{y_m t} \left(\ln y_{mit+1}^* + \ln y_{mit}^* \right) \right], \tag{8}
$$

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[3] 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 $\sum_{m=1}^{M} \beta_{y_m} = 1$, $\sum_{n=1}^{M} \beta_{y_m y_n} = 0 \ \left(m = 1, \ldots, M \right)$, $\sum_{m=1}^{M} \beta_{x_k y_m} = 0 \ \left(k = 1, \ldots, K \right)$ and $\sum_{m=1}^{M} \beta_{y_m t} = 0$

[4] By using the computer program, FRONTIER (Coelli, 1996a)

$$\ln \Delta SEC_o^{vrs} = \frac{1}{2}\sum_{k=1}^{K}\left[\left(-\sum_{k=1}^{K} e_{kit+1} - 1\right)\cdot s_{kit+1} + \left(-\sum_{k=1}^{K} e_{kit} - 1\right)\cdot s_{kit}\right]\cdot \ln\left(\frac{x_{kit+1}}{x_{kit}}\right), \tag{9}$$

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

In order to examine the effects on the input- and output-biased TCs from the MPI in equation (2), Fuentes et al (2001) presents a parametric distance function approach of the period t MPI decomposition. Therefore, a parametric distance function approach of the MPI decomposition between periods t and $t+1$ can be derived in the same manner. The MPI in equation (2) requires a CRS assumption on production technology.

The estimating form of the translog output distance function under the CRS model yield[5]

$$\begin{aligned}
-\ln y_{Mit} + \ln x_{Kit} &= \beta_0 + \beta_{y_m}\sum_{m=1}^{M-1}\ln y_{mit}^* + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{y_m y_m}\ln y_{mit}^* \ln y_{mit}^* + \sum_{k=1}^{K-1}\beta_{x_k}\ln x_{kit}^* \\
&+ \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{x_k x_l}\ln x_{kit}^* \ln x_{lit}^* + \sum_{k=1}^{K-1}\sum_{m=1}^{M-1}\beta_{x_k y_m}\ln x_{kit}^* \ln y_{mit}^* + \beta_t t + \frac{1}{2}\beta_{tt} t^2 \\
&+ \sum_{k=1}^{K-1}\beta_{x_k t}\ln x_{kit}^* t + \sum_{m=1}^{M-1}\beta_{y_m t}\ln y_{mit}^* t - \ln D_{it}^o,
\end{aligned} \tag{10}$$

where $x_{kit}^* = \left(x_{kit}/x_{Kit}\right)$ and $-\ln D_{it}^o = v_{it} - u_{it}$.

The components of the MPI in equation (3) and (4) can be computed after equation (10) is estimated. The magnitude of TC for the period t, the output- and input-biased TC between periods t and $t+1$ in terms of the parameter estimates of the output distance function in equation (10) yield, respectively,

$$\ln \Delta M_o^{crs} = -\beta_t - \beta_{tt}\left(t + 1/2\right) - \sum_{k=1}^{K-1}\beta_{x_k t}\ln x_{kit}^* - \sum_{m=1}^{M-1}\beta_{y_m t}\ln y_{mit}^*, \tag{11}$$

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[5] By normalizing the K-th input quantity to satisfy an additional restriction of homogeneity of degree -1 in inputs where $\sum_{k=1}^{K}\beta_{x_k} = -1$, $\sum_{l=1}^{K}\beta_{x_k x_l} = 0 \ \left(k = 1,\ldots,K\right)$, $\sum_{k=1}^{K}\beta_{x_k y_m} = 0 \ \left(m = 1,\ldots,M-1\right)$ and $\sum_{k=1}^{K}\beta_{x_k t} = 0$

$$\ln OB\Delta T_o^{crs} = -\frac{1}{2}\sum_{m=1}^{M-1}\beta_{y_m t}\ln\left(y_{mt+1}^{*}/y_{mt}^{*}\right), \tag{12}$$

$$\ln IB\Delta T_o^{crs} = -\frac{1}{2}\sum_{k=1}^{K-1}\beta_{x_k t}\ln\left(x_{kt+1}^{*}/x_{kt}^{*}\right). \tag{13}$$

3. Data

Data set 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 is 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 originally founded the EU including Norway and Switzerland. 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 Soviet Union including Turkey. The data is obtained from the FAO and contain the agricultural output and input quantities. In this study, the production technology is presented by two outputs and five inputs. The definitions of these variables are summarised as follows: Output series for the two outputs (i.e. crop and livestock) are derived by aggregating detailed output quantity data on 127 agricultural commodities (115 crop commodities of average 1999-2001 and 12 livestock commodities). 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[6]. The next step is to extend the average base period output series 1999-2001 to cover the whole study period 1992-2002. This is achieved using the FAO production index for crops and livestock separately[7].

[6] Detailed information on how international average prices are constructed see Rao (1993)
[7] See the FAO STAT (FAO, 2004) for details regarding the construction of production index numbers.

Given the constraints on the number of input variables that could be used in the analysis, only five inputs are chosen for the study. Definitions of these input variables are follows. Land input represents the arable land, land under permanent crops and the area under permanent pasture in hectares. Tractor input represents the total number of wheel and crawler tractors used in agriculture. Labour input 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 represents the sum, in nutrient-equivalent terms, the commercial use of nitrogen, potassium, and phosphate expressed in thousands tons. Livestock input is the sheep-equivalent of 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.

4. Results

Table 1: Estimated Parameters of the Output Distance Model[a]

Parameter	VRS Model		CRS Model	
	Estimates	*t*-Statistic	Estimates	*t*-Statistic
β_0	0.3694	8.4473	0.3731	12.1027
β_{y1}	0.2986	12.7308	0.2984	12.6969
β_{y1y1}	0.8281	9.4575	0.7190	8.5861
β_{x1}	-0.1175	-5.2767	-0.1686	-6.7910
β_{x2}	-0.1945	-9.2042	-0.1580	-9.1738
β_{x3}	-0.2154	-8.3084	-0.2429	-10.7577
β_{x4}	-0.0259	-1.0267	-0.0367	-1.5445
β_{x5}	-0.4675	-10.9166		
β_{x1x1}	0.0936	2.1319	-0.0511	-1.3885
β_{x2x2}	0.0010	0.0288	0.0005	0.0156
β_{x3x3}	-0.1328	-5.0181	-0.1506	-5.3123
β_{x4x4}	0.3414	6.8838	0.3275	6.5980
β_{x5x5}	0.4778	4.1586		
β_{x1x2}	-0.0455	-1.3196	-0.0134	-0.3712
β_{x1x3}	0.0943	3.0327	0.0281	0.8866
β_{x1x4}	-0.1264	-3.7959	-0.0660	-2.1123
β_{x1x5}	-0.0897	-1.4725		
β_{x2x3}	0.1276	7.1548	0.1025	5.6955
β_{x2x4}	-0.0554	-1.8007	-0.0446	-1.5798

β_{x2x5}	-0.1225	-1.9714		
β_{x3x4}	0.0760	1.7289	0.0560	1.4690
β_{x3x5}	-0.0860	-1.2925		
β_{x4x5}	-0.1442	-2.0204		
β_{x1y1}	-0.1999	-3.5792	-0.0970	-1.9060
β_{x2y1}	-0.1379	-3.7666	-0.0894	-2.5437
β_{x3y1}	-0.1351	-3.7880	-0.1621	-4.2278
β_{x4y1}	-0.1762	-3.1119	-0.1373	-2.5177
β_{x5y1}	0.5039	5.6849		
β_{t}	-0.0257	-8.2120	-0.0285	-8.5171
β_{tt}	0.0023	1.0809	0.0016	0.6952
β_{x1t}	-0.1789	-3.7616	-0.1206	-2.3928
β_{x2t}	-0.0121	-0.2991	0.0037	0.0850
β_{x3t}	0.0424	0.8754	0.0829	1.6432
β_{x4t}	0.1328	2.5739	0.0832	1.5929
β_{x5t}	0.0995	1.2228		
β_{y1t}	-0.0599	-0.9429	-0.0542	-0.8118
σ^2	0.0754	5.6135	0.1039	8.4026
γ	0.7186	5.7077	0.8050	13.3691

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

We began by estimating the translog output distance function under the VRS in equation (6) and the CRS in equation (10)[8]. The two sets of ML estimates are presented in Table 1. The overall estimated results from both models are very similar and provide the same sign for all parameter estimates except for the estimated parameters, β_{x1x1} and β_{x2t}. 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 estimates of the output elasticities under VRS model are 0.2986 and 0.7014 for crops and livestock, respectively, while the CRS model estimates of the output elasticities are 0.2984 and 0.7016 for crops and livestock, respectively. The estimates of the input elasticities under the VRS model are –0.1175, –0.1945, –0.2154, –0.0259 and –0.4675 for land, tractors, fertilizer, labor, and livestock, respectively, while the CRS model estimates of the input elasticities are –0.1686, –0.1580, –0.2429, –0.0367 and –0.3939 for land, tractors, fertilizer, labor,

[8] Prior to estimation, all variables are scaled to have unit means. Livestock output and livestock input variables are used as the normalizing output and input (see equation 6 and 10). Hypothesis tests regarding the structure of production technology such as the presences of TE and TC are conducted using the likelihood ratio tests. All null hypotheses are rejected which imply the existences of TE and TC in the model.

and livestock, respectively. The sum of the input elasticities from the VRS model provides information on scale economies and 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 1 provide estimates of the average annual rate in TC. The output distance function estimates suggest that the technology is improving at a rate of 2.57% per annum in the VRS model and 2.85% per annum in the CRS model[9]. Then, the parameter estimates of the VRS model are used to calculate the components of the Malmquist TFP growth decomposition whereas those from the CRS model are used to calculate the measures of input- and output-biased TC[10].

Table 2: Weighted Growth Rates of the Malmquist TFP Growth Decomposition by Group of the Countries (in %)

Period	Region	TEC	TC	SEC	TFPC
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

[9] Following the estimation, tests of the regularity conditions are checked at each data point in all 506 observations. We find the convexity condition and the monotonicity constraints in outputs are satisfied at all observations in the output distance function for both models. The monotonicity constraints in inputs are violated at 12, 0, 2, 14, and 0 % of all observations in the case of land, tractors, fertilizer, labour and livestock inputs, respectively, for the VRS model whereas the monotonicity constraints in inputs are violated at 12, 1, 0, 15, and 0 % of all observations in the case of land, tractors, fertilizer, labour and livestock inputs, respectively, for CRS model.

[10] The results of unweighted average values of TE scores and the components of the Malmquist TFP growth decomposition for each country over the sample time period are available by the author request

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

Table 2 presents weighted growth rate of TFP decomposition by the group of the countries during 1992-2002. TFP growth by all countries increases by 16.80 % over the sample period with a weighted average of about 1.527 % per annum. Overall, TC and SEC increase by 16.46 and 0.59 % over the sample period for a weighted average of about 1.496 and 0.054 % per annum, respectively, whereas TEC decreases by 0.3 % over the sample period with a weighted average of about –0.027 % per annum. The EU-15 indicated the TFP growth increases by 14.2 % over the sample period with a weighted average of about 1.292 % per annum. TC and SEC increase by 14.9 and 0.66 % over the sample period for a weighted average of about 1.355 and 0.060 % per annum, respectively, whereas SEC decreases by 1.26 % over the sample period with a weighted average of about –0.114 % per annum.

There were deceleration in TEC during the periods 1992-1996 and deceleration in SEC during the periods 1992-1994. The TFP growth by the EU-15 was low during 1992-1994 and 2000-2002. The EU-10 indicated the TFP growth increases by 15.3 % over the sample period with a weighted average of about 1.392 % per annum. TEC and TC increase by 1.28 and 13.87 % over the sample period for a weighted average of about 0.117 and 1.261 % per annum, respectively, whereas SEC decreases by 0.02 % over the sample period with a weighted average of about –0.002 % per annum. There were deceleration in TEC during the periods 1992-1994 and also deceleration in SEC during the periods 1994-1998 and 2000-2002. The TFP growth by the EU-10 was low during the periods 1998-2002. The transition countries indicated the TFP increases by 20.70 % over the sample period with a weighted average of about 1.882 % per annum. TEC, TC and SEC increase by 0.45, 19.53 and 0.53 % over the sample period for a weighted average of 0.041, 1.775 and 0.048 % per annum, respectively. There were slowdowns in TEC during the periods 1992 to 1998 and also in SEC during the periods 1998-2000. The TFP growth by the transition countries was low during the period 1994-1996. TFP growth for each group of countries was mainly driven by technology progress. The results indicate deterioration in TE by the EU-15 but acceleration in TE by the EU-10 and transition countries. This result implies that the EU-10 and transition countries increased the outputs by improving TE more than the EU-15. Technological progress by the transition countries was higher than the EU-15 and 10 respectively. The results show deterioration in SE by the EU-10 but acceleration in SE by the EU-15 and transition countries.

Table 3: Weighted Growth Rates of TC Decomposition by Group of the Countries (in %)

Period	Region	Magnitude TC	Output-Biased TC		Input-Biased TC				
			Output1	Output2	Input1	Input2	Input3	Input4	Input5
1992-1994	EU15	2.047	-0.057	0.008	-0.010	0.000	-0.044	0.095	-0.018
1994-1996	EU15	1.676	0.087	-0.021	-0.009	0.001	-0.036	0.097	0.008
1996-1998	EU15	1.542	-0.011	-0.017	-0.004	0.001	0.043	0.100	-0.006
1998-2000	EU15	1.202	0.048	0.004	-0.015	0.001	0.141	0.102	-0.003
2000-2002	EU15	1.217	-0.034	-0.006	-0.006	0.000	0.096	0.113	-0.024
1992-2002	EU15	2.296	0.009	-0.009	-0.012	0.001	0.054	0.140	-0.011
1992-1994	EU10	1.720	0.002	0.144	-0.006	-0.004	-0.161	0.064	-0.141
1994-1996	EU10	1.573	0.113	-0.026	-0.013	-0.002	-0.143	0.071	-0.059
1996-1998	EU10	1.200	0.001	-0.019	-0.006	0.000	0.048	0.073	-0.029
1998-2000	EU10	1.187	-0.091	0.038	-0.019	-0.003	-0.052	0.076	-0.086
2000-2002	EU10	0.863	-0.037	-0.025	-0.030	-0.001	-0.041	0.082	-0.021
1992-2002	EU10	1.928	-0.003	0.030	-0.020	-0.003	-0.095	0.100	-0.092
1992-1994	Trans	1.643	-0.130	0.073	-0.011	0.003	1.155	0.061	-0.079
1994-1996	Trans	2.597	-0.002	0.112	0.011	0.006	0.052	0.062	-0.133
1996-1998	Trans	2.441	-0.071	0.049	-0.026	0.005	0.165	0.063	-0.133
1998-2000	Trans	2.192	0.085	0.024	-0.013	0.005	0.000	0.063	-0.048
2000-2002	Trans	2.149	0.100	-0.007	0.017	0.000	-0.124	0.060	-0.039
1992-2002	Trans	3.428	-0.005	0.069	-0.006	0.005	0.341	0.085	-0.117
1992-1994	All	1.853	-0.079	0.047	-0.010	0.001	0.418	0.078	-0.054
1994-1996	All	2.009	0.057	0.028	-0.002	0.002	-0.015	0.082	-0.051
1996-1998	All	1.826	-0.029	0.007	-0.011	0.002	0.086	0.084	-0.054
1998-2000	All	1.543	0.048	0.014	-0.015	0.002	0.074	0.086	-0.026
2000-2002	All	1.524	0.015	-0.008	0.000	0.000	0.003	0.091	-0.029
1992-2002	All	2.651	0.003	0.024	-0.010	0.002	0.155	0.116	-0.058

[a] $Output_1$ = crops; $Output_2$ = livestock output and $Input_1$ = land; $Input_2$ = tractors; $Input_3$ = fertilizer; $Input_4$ = labor; $Input_5$ = livestock input

Table 3 presents weighted growth rate of TC decomposition by the group of the countries during 1992-2002. The sum of input-biased TC, which is larger than that of output-biased TC, implies TC is biased on the inputs more than on the outputs. Transition countries show input- and output-biased TC more than the EU-10 and 15, respectively. Overall, output-biased TC by all countries increases by 0.30 % over the sample period with a weighted average of about 0.027 % per annum. The sum of input-biased TC by all countries increases by 2.24 % with a weighted average of about 0.204 % per annum. TC is biased toward tractors, fertilizer and labor but against land and livestock input. These results illustrate that the direction of TC is tractors-, fertilizer- and labor-using but land- and livestock input-saving. The EU-15 show the sum of output-biased TC is equal one, while the sum of input-biased TC increases by 1.89 % over the sample period with a weighted average of about 0.172 % per annum. TC is biased toward crop at the same rate as it is biased against livestock output. On the input side, TC is biased toward tractors, fertilizer and labor but against land and livestock input. These results imply that the direction of TC is tractors-, fertilizer- and labor -using but land- and livestock input-saving. The EU 10 show the sum of output-biased TC increases by 0.30 % over the sample period with a weighted average of about 0.027 % per annum. TC is biased toward livestock output but against crop. The sum of input-biased TC decreases by 1.21 % over the sample period with a weighted average of about –0.109 % per annum. TC is biased toward land, tractors, fertilizer and livestock input while it is biased against labour. These results imply that the direction of TC is land-, tractors-, fertilizer- and livestock input-using but labor-saving. The transition countries show the sum of output-biased TC increases by 0.70 % over the sample period with a weighted average of about 0.064 % per annum. The sum of input-biased TC increases by 3.36 % over the sample period with a weighted average of about 0.307 % per annum. TC is biased toward tractors, fertilizer and labor but against land and livestock input. These results imply that the direction of TC is tractors-, fertilizer- and labor -using but land- and livestock input-saving.

5. Conclusions

This study integrates a parametric distance function approach presented in Fuentes et al (2001) and Orea (2002) to measure the MPI decomposition. The MPI can be decomposed into TC, TEC and SEC in which TC is decomposed into input- and output- biased TCs and the magnitude of TC. 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 decomposition of Malmquist TFP growth and TC will provide insightful information for researchers in designing policies to achieve a high growth rate in transition countries.

The empirical findings indicate that the weighted average TFP growth in the European agriculture over the study period grew at 1.527 % per annum which was driven by –0.027 % in TEC, 1.496 % in TC and 0.054 % in SEC. Turning to the performance of the different groups of countries, the EU-15 operated at higher TE levels than the EU 10 and transition countries over the study periods, respectively. The weighted average TFP growth grew at 1.292 % per annum by the EU-15, 1.392 % per annum the EU-10 and 1.882 % per annum by 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 TE more than those located within the EU-15. Transition countries indicated impressive “catch-up” effect comparing with the EU-15 and 10. Finally, the transition countries showed input- and output-biased TC more than the EU-10 and 15, respectively.

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