Agricultural Productivity in the EU: A TFP Comparison between the Old (EU-15) and New (EU-10) EU Member States

Lajos BARÁTH[A*], **Imre FERTŐ**[B]
[a] Research Centre for Economic and Regional Studies, HAS
[b] Corvinus University of Budapest, Research Centre for Economic and Regional Studies, HAS

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Abstract

Over the last decades agricultural productivity and efficiency development in the EU have been widely analysed. However, most of the examinations are not adequate to make multilateral comparisons. Although, there are some studies reported TFP indexes which can be used to compare TFP level among countries, they examined only western European countries and the examined time period last until 2007. Consequently, there is a clear lack of investigations into the agricultural TFP level in the new member states (NMS) and there is limited information about the level of agricultural TFP in the EU after 2007. The aims of this paper therefore are: (1) to decompose agricultural productivity indexes for the European agriculture from 2001-2010 and (2) to analyse whether there is a convergence or divergence between the old (OMS) and (NMS) in terms of TFP levels? The analysis is conducted using the framework developed in O'Donnell (2008). For empirical analysis we use the *Lowe TFP index.* The paper analyses country level panel data for EU-25 countries, using data from the Economic Account for Agriculture. Preliminary results imply a convergence between the OMS and NMS.

Keywords Total factor Productivity (TFP) level, Agricultural productivity in the EU; Lowe index; TFP components

JEL code Q12

1. Introduction

To ensure a fair standard of living for the agricultural community of the European Union (EU), improving productivity was a founding principle of the Common Agricultural Policy (CAP) enunciated in the Treaty of Rome. Although CAP has encountered new challenges over time, improving productivity is still one of its central aims.

Effective agricultural and rural policy requires identification the main drivers of total factor productivity growth. Agricultural productivity and efficiency development in the EU have been widely analysed over the past few decades (e.g., Davidova et al., 2003; Brümmer et al., 2002; Fogarasi-Latruffe, 2009; Swinnen and Wranken, 2010; Ball et al., 2001, 2010; Timmer et al., 2010). However, most of the estimates reported in these studies can be used only for bilateral comparisons (i.e. comparing two points in time). Only the Ball et al. (2001, 2010) and Timmer et al. (2010) studies provided information concerning relative TFP level across countries. Nevertheless, it is now widely accepted that understanding the pattern of crosscountry growth and productivity requires estimates of relative levels (Timer et al., 2010). Therefore one of our main goals is to estimate TFP level across European countries.

Moreover, earlier studies examined TFP level across European countries, investigated only western European countries and period that lasted until 2007. Consequently, there is a clear lack of investigation into the comparison of agricultural TFP level between the old (OMS) and new member states (NMS), and we have limited information about both the agricultural TFP growth and level in the EU after 2007.

Additionally, the EU-10 countries joined the EU ten years ago, and certain questions arise. How did their TFP levels develop following accession? Have their TFP levels approached those of the old member states? Are the drivers of productivity in the OMS and NMS similar or different?

The aims of this paper are threefolds. First, to decompose European agriculture productivity indexes that covers the 2000-2010 period. Second, to analyse whether accession changed the patterns of efficiency and TFP in the NMS. Third, to analyse whether the OMS and NMS converge or diverge in terms of their TFP development.

The analysis in this paper is conducted within the aggregate quantity framework first developed in O'Donnell (2008). For purposes of empirical analysis we use the Lowe index, which is, economically ideal, as it satisfies all economically relevant axioms and tests from index number theory, including the identity axioms and transitivity test. This means it can be used to make reliable multi temporal (i.e. many period) and multi-lateral (i.e. many firm/country) comparisons of TFP and efficiency (O'Donnell, 2011).

The remainder of this paper is organised as follows. First, we describe the methods used in the analysis and our dataset. Next, we present the empirical results on TFP level and differences between the old and new member states. Then we test the convergence or divergence between OMS and NMS using panel unit root tests. Finally, we conclude.

2. Methodology

First, we present the advantages of aggregate quantity framework developed by O'Donnell and the estimation of Lowe index. Then we outline the DEA model applied to decompose the Lowe index and the cluster analysis used to identify different technologies among European countries.

2.1. Productivity level estimation and decomposition of the Lowe TFP index

The TFP analysis in this paper is conducted within the aggregate quantity framework first developed in O'Donnell (2008).

To empirically measure the components of productivity growth, first a productivity index number formula is needed. Index numbers that measure changes in TFP can be expressed as the ratio of an output quantity index to an input quantity index. O' Donnell (2010) use the term, multiplicatively complete to refer to an index numbers constructed in this way. To express it formally, "let $\boldsymbol{x}_{it} = (x_{1it,\dots,}x_{kit})'$ and $\boldsymbol{q}_{it} = (q_{1it,\dots,}q_{Jit})'$ denote the input and output vectors of firm i in period t. Then a TFP index that measures the TFP of firm i in period t relative to the TFP of firm h in period s is:

$$TFP_{hs,it} = \frac{TFP_{it}}{TFP_{hs}} = \frac{Q_{it}/X_{it}}{Q_{hs}/X_{hs}} = \frac{Q_{hs,it}}{X_{hs,it}}, \text{ (1) where}$$

$Q_{it}\equiv$ Q($\boldsymbol{q}_{it}$) is an aggregate output and $X_{it}\equiv$ X($\boldsymbol{x}_{it}$) is an aggregate input. Additionally, Q(.) and X(.) are aggregator functions (O'Donnell, 2012). Different aggregator functions give rise to different TFP indexes. The only requirements concerning aggregator functions are that they be nonnegative, nondecreasing and linearly homogeneous. The class of such kind of functions include Laspeyres, Paasche, Fischer, Lowe, Malmquist, Hicks-Moorsteen and Färe-Primont.

The Laypeyres, Paashe, Törnquist, Hicks-Moorsten and Fisher TFP indexes are all multiplicatively complete (O'Donnell, 2012). However, a problem with these indexes is that they fail to satisfy a transitivity axiom. Transitivity guarantees that the direct comparison of two observations will yield the same estimate of TFP change as an indirect comparison through a third observation. The usual solution to the transitivity problem is the EKS method, which was proposed by Elteto and Koves (1964) and Szulc (1964). However, these so called EKS indexes fail to satisfy the identity axiom. The identity axiom guarantees that if outputs and inputs are unchanged then the TFP index will take the value one indicating that productivity is also unchanged (O'Donnell, 2012).

In this article following O'Donnell, 2012 we use the Lowe TFP index. The Lowe index is, economically ideal, as it satisfy all economically relevant axioms and tests from index number theory, including the identity axioms and transitivity test. This means it can be used to make reliable multi temporal (i.e. many period) and multi-lateral (i.e. many country) comparisons of TFP and efficiency (O'Donnell, 2011).

The Lowe TFP index can be written as follows:

$TFP_{hs,it} = \frac{Q_{hsit}}{X_{hsit}} = \frac{\boldsymbol{p}_0'\boldsymbol{q}_{it}}{\boldsymbol{p}_0'\boldsymbol{q}_{hs}} \frac{\boldsymbol{w}_0'\boldsymbol{x}_{hs}}{\boldsymbol{w}_0'\boldsymbol{x}_{it}}$, (2) where

$\boldsymbol{p}_0$ and $\boldsymbol{w}_0$ are pre-determined firm- and time invariant reference prices. Any number of price vectors can be used as reference price vectors. O'Donnell recommends using price vectors that are representative of the price vectors faced by all firms that are to be compared.

Moreover, O'Donnell (2008) showed that any multiplicatively-complete TFP index can be decomposed into a measure of technical change and measures of efficiency change. A possible decomposition can be written as follows:

$$TFP_{hs,it} = \frac{TFP_{it}}{TFP_{hs}} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{TFPE_{st}}{TFPE_{hs}}\right) \text{ (3),}$$

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} \text{ , (4) where}$$

TFP_t^* is the maximum possible TFP using the technology available at time t. The term TFP_t^*/TFP_s^* measures the change in the maximum TFP possible using the production technologies available in periods s and t, which can be seen as a measure of technical change. $TFPE_{it}$ measures the overall productive efficiency of a firm, so that the second term in equation 3 is a measure of overall efficiency change. This term can be further decomposed into various measures of technical, scale and mix efficiency change. For example,

$$TFPE_{it} = \left(\frac{OTE_{it}}{OTE_{hs}}\right)\left(\frac{OSME_{it}}{OSME_{hs}}\right)\text{, (5) where}$$

$OSME_{it}$ is a combined measure of scale and mix efficiency change.

2.2 Identifying groups of countries with different technologies using Cluster analysis

Decomposing the TFP index into measures of technical and efficiency change involves estimating a production frontier. However, estimations of production frontiers typically rely on the assumption that every decision-making unit (DMU) has the same technology. As our aim is to estimate the TFP indexes of EU-25 countries, the assumption of a common technology is certainly strong.

Nevertheless, there are several techniques to identify different technologies within a sample: they can be identified using statistical procedures such as cluster analysis or econometric techniques (Alvarez et al., 2010).

We employ a cluster analysis to account for the environmental and technological differences among countries. In this we follow – with some modification– the approach of Sommer and Hines (1991), who used Ward's minimum variance method to identify different production patterns in US agriculture. They used this method to combine counties into groups that are homogeneous in three dimensions: farm enterprise, farm resources and farm-nonfarm sector interaction.

Our purpose was to identify groups with different production patterns, technological and environmental conditions. Therefore, in order to identify different groups of countries, we used variables associated with types of production, production technology and weather conditions. Following Sommer and Hines (1991) the variables were transformed into a standard normal distribution (called Z-scores) with zero mean and unit variance to give all variables equal weight in the cluster analysis.

2.3. Estimation of group frontiers

In this paper we estimate the frontier and associated measures of efficiency using Data Envelopment Analysis (DEA). To account for technological differences we estimate separate production frontiers for the groups identified by cluster analyses. Additionally, following O'Donnell (2012), to account for temporal variations in environmental factors, these technologies have been estimated using DEA models that allow for a small amount of technical regress. This involves using a moving window of observations to estimate the technology in each region.

DEA linear programs (LPs) for estimating technical and scale efficiency are well-known in the literature. For instance, LPs for measuring Farrel (1957) measure of output oriented *technical efficiency* of firm i in period t can be obtained by solving:

$$OTE_{it} = D_o(x_{it}, q_{it}, t) = \min_{\lambda,\theta}\{\lambda^{-1}: \lambda q_{it} \leq Q\theta; X\theta \leq x_{it}; \theta_\iota' = 1; \lambda, \theta \geq 0\}. \ (6)$$

Output oriented scale efficiency can be estimated as:

$$OSE_{it} = OTE_{it}^{VRS}/OTE_{it}^{CRS}, \text{ (7) where}$$

OTE_{it}^{VRS} and OTE_{it}^{CRS} are solutions to LP(6) under variable returns to scale and constant returns to scale, respectively. OTE_{it}^{CRS} can be estimated if the condition of $\theta_\iota' = 1$ is deleted from the Lp(6).

LPs for measuring levels of mix and scale-mix efficiencies have been developed by O'Donnell (2010) and O'Donnell, (2010b) and was extended in O'Donnell (2012) how DEA can be used to the estimation of measures of efficiency associated with Paasche, Laspeyres, Fisher and Lowe TFP indexes. Measures of the output Mix efficiency change component of the Lowe TFP index are obtained by solving the following LP:

$$OME_{it} = \min_{\theta,z}\{\boldsymbol{p}_0'\boldsymbol{q}_{it}/\boldsymbol{p}_0'\boldsymbol{z}: \boldsymbol{z} \leq \boldsymbol{Q\theta}; \boldsymbol{X\theta} \leq \boldsymbol{x}_{it}; \boldsymbol{\theta}_\iota' = 1; \boldsymbol{\theta}, \boldsymbol{z} \geq 0\}, \text{ (8) where}$$

$z = \lambda q_{it}$.

The maximum possible TFP using the technology available in period t in the case of the Lowe index can be estimated as (O'Donnell,2012):

$$TFP_t^* = \min_{\theta,z,v}\{\boldsymbol{p}_0' z: \boldsymbol{z} \leq \boldsymbol{Q\theta}; \boldsymbol{X\theta} \leq v; \boldsymbol{w}_0'\boldsymbol{v} = \boldsymbol{1}; \boldsymbol{\theta}_\iota' = 1; \boldsymbol{\theta}, \boldsymbol{z}, \boldsymbol{v} \geq 0\}. \text{ (9)}$$

The difference in the maximum TFP possible in two periods is a natural measure of technical change.

3. Data

For the empirical analysis we use country-level panel data from the Economic Account for Agriculture (EAA) database covering the 2000-2010 period. Our aim is to compare the performance of the old and new member states. The old member states contain the EU-15 countries, whereas the new member states include the EU-10 countries that joined to EU in May 2004, except Cyprus and Malta. We excluded Malta and Cyprus, because of missing data.

For the purpose of DEA frontiers estimation, two outputs (Q_1 – crop Output and Q_2 animal output) and four inputs (labour in Annual Work Unit[1] [x_1], utilised agricultural area in hectares [x_2], Fixed capital consumption (FCC) in value [x_3] and total intermediate consumption (TIC) in value [x_4]) were used. All of the variables expressed in nominal prices were deflated to 2005 prices with the use of the appropriate deflators; precisely, the outputs (Q) were deflated by the crop and animal output price indexes, respectively. The total intermediate consumption (x_4) by the price index of purchased goods and services and the corresponding values of fixed capital consumption (x_3) by the price index of agricultural investments.

Some descriptive statistics are included in Table 1, separately for OMS and NMS.

[1] One Annual Work Unit (AWU) corresponds to the work performed by one person on an agricultural farm performing agricultural activities on a full-time basis (1 AWU = 1800 working hours = 225 working days. (Keszthely and Pesti, 2009).

Table 1: Variable definitions and descriptive statistics

Variable	Symbol	Mean	Std. Deviation	Minimum	Maximum
OMS					
Crop Output	Y	8837.56	9511.63	103.71	31831.1
Animal Output		7304.49	6553.51	144.98	22081.8
Labour	X_1	392.707	386.95	3.6	1396
Land	X_2	9152.05	9584.43	128	29766
FCC	X_3	2951.23	3329.51	60.64	12251.5
TIC	X_4	10068.9	9657.46	155.98	36024.7
NMS					
Crop Output	Y	1596.04	1948.18	158.64	7021.04
Animal Output		1705.00	2282.63	236.37	8207.11
Labour	X_1	438.726	725.498	25.4	2524.3
Land	X_2	4323.19	4942.34	468	18413
FCC	X_3	422.194	461.984	22.86	1649.48
TIC	X_4	2379.23	2810.26	277.02	9415.06
All countries					
Crop Output	Y	6318.77	8493	103.71	31831.1
Animal Output		5356.84	6073.73	144.98	22081.8
Labour	X_1	408.713	528.811	3.6	2524.3
Land	X_2	7472.45	8574.75	128	29766
FCC	X_3	2071.56	2957.16	22.86	12251.5
TIC	X_4	7394.21	8768.71	155.98	36024.7

Source: Own calculations.

For the identification of different technological and environmental characteristics with cluster analysis, we used three groups of variables: 1. the share of main agricultural products and secondary activities in total output; 2. Indexes accounting for technological differences: output-land ratio, land-man ratio and output-labour ratio; 3. environmental conditions: mean annual temperature and average precipitation. The variables used and the associated z-scores are presented in Annex 1.

Furthermore, the estimation of Lowe TFP indexes involves selecting representative price vectors p_0 and w_0. In this paper we use the arithmetic mean of the shadow prices associated with the LP (6) estimated for the identified 5 groups of countries.

4. Results

First, we present the results of TFP level and components assuming one common frontier to all countries. Second, the five groups of countries identified by cluster analysis is reported. Third, we present the results of TFP and components estimates assuming different frontiers for the 5 groups obtained.

4.1. TFP estimates assuming a common frontier to all countries

The development of TFP change is shown in Table 2. Since the reported TFP indexes are transitive they can be used to make meaningful comparisons of performance across both countries and time. The values that are marked with “h” are the highest among the 23 countries analysed, while those marked with “l” are the lowest. The maximum possible TFP and its change (i.e. the technical change) is the same for all countries, as in this section one common frontier was estimated to all countries.

Table 2 shows that the highest level of TFP was in Spain, both in 2000 and 2010, whilst the lowest level was in both years in Finland. Additionally, it can be seen that the biggest change regarding TFP between 2000 and 2010 was in Poland, where was a 124% increase in TFP; the estimated TFP increased in Poland due to a 3% increase in technical change and a 20% increase in overall efficiency.

Moreover, Table 2 reports estimates for OMS and NMS. The reported estimates for the OMS and NMS are simple arithmetic means of the individual country estimates within each group. It can be seen that the TFP level is higher in the OMS; however, the difference is decreased between 2000 and 2010, which suggest that there is a moderate convergence between OMS and NMS concerning TFP.

Table 2: TFP and its component change

	TFP			**TFP_Max**			**TFPE**		
Countries	**2000**	**2010**	**2010/2000**	**2000**	**2010**	**2010/2000**	**2000**	**2010**	**2010/2000**
Austria	0.90	0.95	1.05	1.47	1.51	1.03	0.61	0.63	1.02
Belgium	1.33	1.19	0.90	1.47	1.51	1.03	0.91	0.79	0.87
CZ	0.97	0.92	0.95	1.47	1.51	1.03	0.66	0.61	0.92
Denmark	1.15	1.17	1.01	1.47	1.51	1.03	0.78	0.77	0.99
Estonia	1.07	0.98	0.92	1.47	1.51	1.03	0.73	0.65	0.89
Finland	0.78[l]	0.78[l]	0.99	1.47	1.51	1.03	0.53[l]	0.51[l]	0.97
France	1.04	1.02	0.98	1.47	1.51	1.03	0.71	0.67	0.95
Germany	1.13	0.99	0.87	1.47	1.51	1.03	0.77	0.65	0.85
Greece	1.27	1.08	0.85[l]	1.47	1.51	1.03	0.87	0.72	0.83[l]
Hungary	0.84	0.83	0.99	1.47	1.51	1.03	0.57	0.55	0.96
Ireland	1.30	1.17	0.90	1.47	1.51	1.03	0.88	0.77	0.87
Italy	1.03	0.92	0.89	1.47	1.51	1.03	0.70	0.61	0.87
Latvia	0.85	0.83	0.99	1.47	1.51	1.03	0.58	0.55	0.96
Lithuania	0.85	0.87	1.03	1.47	1.51	1.03	0.58	0.58	1.00
Luxembourg	0.99	1.11	1.13	1.47	1.51	1.03	0.67	0.74	1.10
Netherlands	1.20	1.14	0.95	1.47	1.51	1.03	0.82	0.75	0.92
Poland	1.01	1.25	1.24[h]	1.47	1.51	1.03	0.69	0.83	1.20[h]

Portugal	1.17	1.14	0.97	1.47	1.51	1.03	0.80	0.75	0.94
Slovakia	0.87	0.92	1.06	1.47	1.51	1.03	0.59	0.61	1.03
Slovenia	1.05	1.05	1.00	1.47	1.51	1.03	0.72	0.69	0.97
Spain	1.43[h]	1.51[h]	1.05	1.47	1.51	1.03	0.98[h]	1.00[h]	1.03
Sweden	0.87	0.85	0.98	1.47	1.51	1.03	0.59	0.56	0.95
UK	1.02	1.06	1.04	1.47	1.51	1.03	0.69	0.70	1.01
OMS_average	1.11	1.07	0.97	1.47	1.51	1.03	0.75	0.71	0.94
NMS_average	0.94	0.96	1.02	1.47	1.51	1.03	0.64	0.63	0.99

Source: own estimation

4.2. Groups of countries obtained by cluster analysis

To account for technological and environmental differences between countries, we identified different groups using cluster analysis. As a result of this procedure we obtained five groups with different technological and environmental conditions. Group 1 contains: Austria, France, Luxemburg, Ireland and Slovakia. Group 2 include: Belgium, Netherlands, Denmark, and Germany. Group 3 include: Czech Republic, Slovakia, Hungary, and Poland. Group 4 contains: Estonia, Latvia, Lithuania, Finland, Sweden. Group 5 includes: Greece, Spain, Italy, and Portugal.

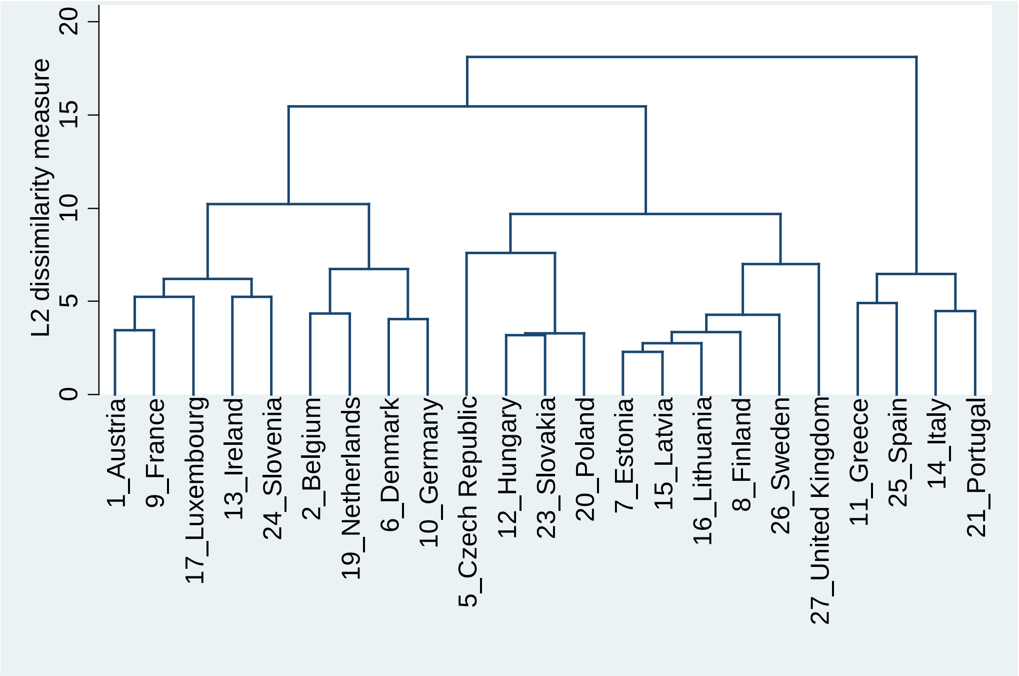

Figure 1: Identification of different clusters

Source: own estimation

In the next step of our analysis, different frontiers were estimated for these groups.

4.3 TFP and its components assuming different frontiers

Table 3 reports estimates in the case when different frontiers were estimated for the groups obtained by cluster analysis. Table 3 shows a slightly different picture compared to our earlier results. Table 3 reveal that the TFP in the Netherland was the highest in both years reported. The biggest change between 2000 and 2010 occurred in Latvia; where the TFP increase was 1.28%, which increase was due to a 1% increase in the maximum possible TFP and a 26% increase in overall efficiency. Similarly to our previous estimation, Table 3 reveals also a remarkable TFP increase in Poland.

Further, the results reveal a bigger difference in TFP level between OMS and NMS compared to the estimation when one common frontier is estimated to all countries. Both the maximum possible TFP and the overall efficiency level are higher in the OMS compared to the NMS. However, the results imply also a moderate convergence between OMS and NMS. In the NMS the increase of maximum possible TFP was bigger, meaning that the NMS experienced a larger technological development over the analysed period. The overall efficiency level is slightly decreased in the NMS, whereas there is a moderate increase in the NMS.

Table 3: The development of TFP and its components assuming different frontiers

	TFP			**TFP_Max**			**TFPE**		
Country	**2000**	**2010**	**2010/2000**	**2000**	**2010**	**2010/2000**	**2000**	**2010**	**2010/2000**
Austria	1.31	1.40	1.07	1.71	1.73	1.01	0.77	0.81	1.06
Belgium	2.12	2.04	0.96	2.36[h]	2.27[h]	0.96[l]	0.90	0.90	1.00
CZ	1.16	1.15	0.99	1.21[l]	1.43	1.19[h]	0.96	0.80	0.83
Denmark	1.72	1.83	1.06	2.36[h]	2.27[h]	0.96[l]	0.73	0.80	1.10
Estonia	0.94	0.98	1.05	1.39	1.41[l]	1.01	0.67	0.70	1.04
Finland	1.11	1.10	0.99	1.39	1.41[l]	1.01	0.80	0.78	0.98
France	1.71	1.67	0.98	1.71	1.73	1.01	1.00[h]	0.97	0.97
Germany	1.75	1.60	0.91	2.36[h]	2.27[h]	0.96[l]	0.74	0.70	0.94
Greece	1.84	1.63	0.88[l]	1.96	2.13	1.09	0.94	0.76	0.81[l]
Hungary	1.09	1.11	1.02	1.21[l]	1.43	1.19[h]	0.90	0.77	0.86

Ireland	1.50	1.37	0.92	1.71	1.73	1.01	0.88	0.79	0.90
Italy	1.85	1.68	0.91	1.96	2.13	1.09	0.95	0.79	0.84
Latvia	0.65[l]	0.77[l]	1.19	1.39	1.41[l]	1.01	0.47[l]	0.55[l]	1.18
Lithuania	0.74	0.95	1.28[h]	1.39	1.41[l]	1.01	0.53	0.67	1.26[h]
Luxembourg	1.65	1.68	1.02	1.71	1.73	1.01	0.97	0.97	1.01
Netherlands	2.36[h]	2.25[h]	0.96	2.36[h]	2.27[h]	0.96[l]	1.00[h]	0.99	0.99
Poland	1.12	1.41	1.26	1.21[l]	1.43	1.19[h]	0.92	0.98	1.06
Portugal	1.70	1.71	1.01	1.96	2.13	1.09	0.87	0.80	0.93
Slovakia	0.91	1.07	1.18	1.21	1.43	1.19[h]	0.75	0.74	0.99
Slovenia	1.54	1.63	1.06	1.71	1.73	1.01	0.90	0.94	1.05
Spain	1.93	2.13	1.10	1.96	2.13	1.09	0.99	1.00[h]	1.01
Sweden	1.23	1.25	1.01	1.39	1.41[l]	1.01	0.89	0.88	1.00
UK	1.35	1.37	1.01	1.39	1.41[l]	1.01	0.97	0.97	1.00
OMS_average	1.67	1.65	0.98	1.88	1.92	1.02	0.89	0.86	0.97
NMS_average	1.02	1.13	1.11	1.34	1.46	1.09	0.76	0.77	1.01

5. Stability Analysis

In this section we focus on the stability of the TFP indices over time. At least two types of stability from one period to the next can be distinguished: (i) stability of the distribution of the TFP indices; and (ii) stability of the value of the TFP indices for particular country.

The first type of stability of the distribution of the TFP indices is capturing convergence/divergence in the productivity. Time series investigation of the convergence hypothesis in economic literature often relies on unit root tests of the null hypothesis on the existence of the panel unit root in time series data, and the alternative is that the times series are stationary. The rejection of the null hypothesis on the existence of the panel unit root is commonly interpreted as evidence that the time series are stationary and have converged to their equilibrium state, since any shock that causes deviations from equilibrium eventually drops out. The extension of these tests to the panel framework has significantly influenced the literature on how to measure the convergence of economic variables. Over the previous decade, a number of panel unit root tests have been developed (Baltagi, 2008). Considering the well-known low-power properties of unit root tests, to check convergences or divergence in the B indices, three panel unit root tests with and without trend specifications, respectively, as deterministic components are used: the Im et al. (2003) method (assuming individual unit root processes), ADF-Fisher Chi-square, and PP-Fisher Chi-square (Maddala and Wu, 1999; Choi, 2001). In addition, the lag length of explanatory variables has been chosen according to the Modified Akaike Information Criterion (MAIC) proposed by Ng and Perron (2001).

TFP indices as such, do not reveal much about the fluctuation of countries' relative performance. From policy point of view however, it is an interesting question whether low performing countries are always inefficient and vice versa, i.e. countries with higher TFP indices are efficient throughout the period. Policy relevance is given by the fact that chronically lower performing countries may be targeted with specific measures in order to improve their efficiency scores. We follow the stability analysis methodology outlined by Barnes *et al.* (2010) and Bakucs et al (2014). Yearly country TFP indices were classified by terciles, then markov transition probability matrices linking two consecutive years were constructed, that indicate whether the considered country remained in the same tercile, or its relative position has worsened, or contrary, improved. Interpretation of persistence or mobility throughout of entire distribution of TFP indices can be studied easily using transition probability matrix. High values of transition probability along diagonal suggest high persistency, whilst high values for off-diagonal elements imply large mobility. We can conclude that in our case there is a high persistency irrespective of the fact that a common or different frontier was estimated (Table 5; Table 6).

To investigate convergence vis-à-vis divergence in the dynamics of the TFP indices, panel unit root tests with, and without trend specifications as a deterministic component are used (Table 4). We find ambiguous results for common frontier estimations, three of six panel unit root tests confirm the existence of panel unit root. However, the empirical results of the three different panel unit root tests clearly reject the existence of the panel unit root hypothesis for different frontier estimations, This implies that the TFP indices by the EU-25 countries are stationary, confirming the hypothesis of convergence. In other words, we find the convergence in the dynamics of the TFP indices in the EU-27 countries. This implies that similar characteristics tend toward a common distribution of the TFP indices, with falling (rising) in the dynamics of the TFP indices in the EU-27 countries of initially high (low) TFP indices.

Table 4: Panel Unit Root Tests for the TFP Indices, 2000-2010 (p-values)

	without time-trend			with time-trend		
	IPS	ADF	PP	IPS	ADF	PP
Common frontier	0.5194	0.5045	0.0302	0.1658	0.0451	0.0000
Different frontier	0.0001	0.0003	0.0000	0.0426	0.0108	0.0000

Note: IPS (Im, Pesaran and Shin W-stat), ADF (ADF-Fisher Chi-square), PP (PP-Fisher Chi-square).

Table 5 Markov matrix for common frontier estimations

	1	2	3
1	0.8182	0.1591	0.0227
2	0.1379	0.7586	0.1034
3	0.0390	0.1039	0.8571

Table 6 Markov matrix for different frontier estimations

	1	2	3
1	0.9205	0.0682	0.0114
2	0.0230	0.8276	0.1494
3	0.0649	0.1169	0.8182

6. Conclusion

In this paper our central aim was to analyse whether the OMS and NMS converge or diverge in terms of their TFP level. In order to fulfil this goal we estimated and decomposed Lowe TFP indexes. First, we estimated a common frontier to all countries; in the next step we estimated different frontiers. Although, our results are preliminary they imply that the TFP level in the OMS was higher compared to the NMS. This difference is mainly caused by the higher technological level in the OMS. Additionally, panel unit root tests suggest a convergence between the OMS and NMS.

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Annex 1: Variables used for cluster analysis and the associated z scores

	CEREALS	Oil seeds	Sugar beet	Fodder maize	Other forage plants	Fresh vegetables	Nursery plants	POTATOES (including seeds)	FRUITS	Tropical fruit
	z1	z2	z3	z4	z5	z6	z7	z8	z9	z10
Austria	-0.26	-0.25	0.79	-0.05	0.24	-0.73	-0.99	-0.39	-0.57	-0.36
Belgium	-0.98	-0.82	0.79	-0.05	0.24	-0.38	0.75	-0.09	-0.57	-0.36
Cz	1.36	3.5	-0.85	-0.79	-0.45	-0.03	-0.41	-0.39	0.24	-0.36
Denmark	1.72	1.48	2.42	1.42	-0.45	-1.07	-0.41	-0.68	-0.57	-0.36
Estonia	0.28	-0.53	-0.03	1.42	0.70	-0.90	-0.99	-0.83	-0.57	-0.36
Finland	0.10	0.62	-0.85	-0.79	0.24	-0.38	1.33	-0.68	-0.57	-0.36
France	-0.08	-0.53	-0.03	-0.79	-0.69	0.31	0.75	-0.53	-0.57	-0.36
Germany	0.46	0.04	0.79	-0.05	0.01	-0.38	-0.41	-0.24	-0.57	-0.36
Greece	0.46	0.04	1.60	2.16	0.24	-0.55	-0.99	-0.68	-0.57	-0.36
Hungary	-0.44	-0.82	-0.85	-0.79	-0.45	1.36	0.17	1.40	1.86	1.24
Ireland	2.08	1.19	-0.03	-0.05	-0.92	-0.03	-0.99	-0.09	0.24	-0.36
Italy	-0.98	-0.82	-0.85	-0.05	1.63	-0.73	-0.41	-0.68	-0.57	-0.36
Latvia	-0.62	-0.82	-0.85	-0.05	-0.69	1.01	-0.99	0.95	1.86	-0.36
Lithuania	1.36	0.91	-0.85	-0.79	0.93	-0.73	0.75	-0.83	-0.57	-0.36
Luxembourg	0.82	0.62	0.79	-0.05	-0.22	-0.90	1.91	-0.83	-0.57	-0.36
Malta	-0.80	-0.53	-0.85	2.89	1.86	-1.07	-0.99	-0.68	-0.57	-0.36
Netherlands	-1.52	-0.82	-0.03	-0.05	-1.15	0.31	0.75	-0.53	-0.57	-0.36
Poland	0.64	0.04	1.60	-0.05	-0.22	-0.21	0.17	-0.24	-0.57	-0.36
Portugal	-1.16	-0.82	-0.85	-0.79	-1.38	0.49	-0.99	2.15	3.48	2.84
Romania	0.64	0.33	-0.85	-0.79	1.40	1.18	1.91	0.21	0.24	-0.36
Slovakia	1.00	1.19	1.60	-0.05	-0.92	-0.55	-0.99	-0.53	-0.57	-0.36
Slovenia	-0.62	-0.53	-0.85	1.42	1.86	-0.73	-0.99	0.36	0.24	-0.36
Spain	-0.26	-0.53	-0.85	-0.79	-0.45	1.36	-0.99	1.70	0.24	3.64
Sweden	-0.26	-0.25	0.79	-0.79	1.63	-0.55	0.17	-0.68	-0.57	-0.36
UK	0.10	-0.25	-0.03	-0.05	-1.15	-0.03	0.17	-0.24	-0.57	-0.36

	Grapes	Olives	WINE	Cattle	Pigs	Sheep and goats	Poultry	SECONDARY ACTIVITIES	Output-land ratio	land-man ratio
	z11	z12	z13	z14	z15	z16	z17	z18	z_y_b	z_b_a
Austria	1.20	0.98	0.67	-0.63	-0.73	0.60	-0.26	-0.27	-0.13	-0.06
Belgium	-0.57	1.15	2.33	0.47	-0.03	-0.93	-0.26	-0.27	1.53	-0.23
Cz	-0.57	-0.96	-1.16	1.02	0.33	1.52	-0.26	-0.27	-0.62	-0.88
Denmark	-0.57	-0.25	-0.06	-0.63	-0.03	-0.62	1.88	4.06	-0.53	0.91
Estonia	-0.57	-0.61	3.06	-0.63	-1.08	-0.62	-0.26	-0.27	0.62	1.57
Finland	-0.57	-0.43	0.31	-0.63	-0.38	1.52	-0.26	-0.27	-0.63	0.76
France	-0.57	-0.25	-0.25	-0.63	-0.38	2.13	-0.26	-0.27	-0.29	0.17
Germany	2.97	0.63	-0.98	-0.08	-0.03	-0.32	-0.26	-0.27	-0.02	0.72
Greece	0.02	-0.08	0.86	-0.63	-0.38	-1.24	-0.26	-0.27	0.22	0.40
Hungary	-0.57	-0.96	-1.53	3.23	-1.43	0.30	-0.26	-0.27	-0.34	-0.40
Ireland	-0.27	-0.96	0.31	-0.08	1.38	-0.62	-0.26	-0.27	-0.51	-0.83
Italy	-0.57	3.44	-0.61	1.02	-1.08	-1.24	-0.26	-0.27	-0.33	-0.01
Latvia	0.61	-0.08	-0.80	-0.63	-0.03	-0.32	-0.26	-0.27	0.40	-0.91
Lithuania	-0.57	-0.61	-0.25	-0.63	-0.73	0.60	-0.26	-0.27	-0.71	-0.27
Luxembourg	-0.57	-0.43	-0.25	-0.63	-0.03	0.91	-0.26	-0.27	-0.63	-0.45
Malta	1.79	1.68	-0.61	-0.63	-1.79	0.60	-0.26	-0.27	0.18	0.74
Netherlands	-0.57	-0.25	0.12	-0.08	-0.73	-0.62	-0.26	-0.27	4.18	-0.99
Poland	-0.57	-0.25	1.04	-0.63	1.73	-0.93	-0.26	-0.27	-0.44	-1.20
Portugal	1.49	-0.25	-0.06	-0.63	1.03	-0.62	-0.26	-0.27	-0.16	-1.04
Romania	-0.27	-1.13	-0.43	-0.08	-0.38	0.91	-0.26	-0.27	-0.46	-1.16
Slovakia	-0.57	0.10	-0.06	-0.63	0.33	0.60	-0.26	-0.27	-0.57	-0.14
Slovenia	2.08	0.80	-0.61	-0.08	1.03	-1.24	-0.26	-0.27	0.09	-1.30
Spain	0.02	-0.43	0.31	0.47	-0.38	-0.32	-0.26	-0.27	-0.20	0.31
Sweden	-0.57	0.10	-0.80	-0.63	-0.73	1.52	-0.26	-0.27	-0.30	1.78
Uk	-0.57	0.80	-0.98	2.13	1.38	0.60	-0.26	-0.27	-0.35	2.50