

Reziti, Ioanna; Zangelidis, Leonidas

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Regional Productivity and Efficiency Growth in Greek Agriculture

Ioanna Reziti^a, Leonidas Zangelidis^b

^a*Center of Planning and Economic Research (KEPE), Athens, Greece.*

Email: ireziti@kepe.gr

^b*National and Kapodistrian University of Athens, KEPE Intern*

Email: leonidaszangelidis@gmail.com

Abstract

In this paper, for the first time, we apply the Färe-Primont productivity index (FPI) to examine the agricultural total factor productivity (TFP), during the period 2004–2016, in four regions of Greece: Macedonia and Thrace (region I), Epirus, Peloponnesus and the Ionian Islands (region II), Thessaly (region III) and Central Greece, the Aegean Islands and Crete (region IV). The FPI is further decomposed into measures of technical change, technical efficiency change, scale and mix efficiency change, residual scale efficiency change and residual mix efficiency change. The results show that TFP has declined for all regions except region II. In region IV, the TFP decrease is due to the deterioration of scale and mix efficiency. In region III, the main factor for the TFP decrease is technical regression. In region I, both technical regression and the deterioration of scale and mix efficiency affect the TFP fall. Region IV experienced the highest decline in TFP mainly due to the large decrease of scale and mix efficiency. Policy implications should try to improve scale and mix efficiency by reallocating resources optimally, especially in regions I and IV. However, the need for increased investment in R&D is unquestionable as it would improve technical change.

Keywords: Greece, Färe-Primont Index, Total Factor Productivity, Technical Efficiency, Scale and Mix Efficiency

JEL Classifications: D24; O47; Q10

1. Introduction

Over the last few decades, productivity and efficiency growth analysis has been of great concern for economic researchers, mostly in developed and developing countries. According to Khan, Salim and Bloch (2014), global agricultural productivity has been falling, particularly in developed countries, where maintaining growth in agricultural productivity is important for improving standards of living. Agricultural productivity has gained renewed interest due to growing food and industrial demand. The world is shifting from demand constrained to supply constrained as a result of population increase. Hence, productivity growth in agriculture is considered essential. The agricultural sector output is expected to grow at a sufficiently rapid rate to meet the continuously increasing demands for food and

raw materials arising out of steady population growth (EU Agricultural Markets Briefs, 2016).

Productivity is defined as a measure of the efficiency in converting inputs into useful outputs. In the case of agricultural production, the evaluation of efficiency is complicated because of climate conditions and the large variety of farms and farm sizes. Productivity analysis is important in order to evaluate the management of a sector, as well as being useful from an economic point of view. On a microeconomic level, productivity analysis could help researchers evaluate the management of a firm and the performance of a sector. On a macroeconomic level, it is helpful for effective social or economic policies. Productivity may be measured using partial indices related to a particular production factor or as TFP. Partial measures are informative, but their main disadvantage is that they overvalue total productivity increases by not taking into account the changes in the outlays of other production factors.

There are different indexes that can be used to measure the changes in the TFP and its components, although some of them are more reliable than others. When prices are available, the most common indexes are Törnqvist and Fischer indexes. However, neither is transitive nor follows the identity axiom (Coeli et al., 2005; Rahaman and Salim, 2013). Additionally, failing the identity axiom means that when two firms produce the same output using the same inputs, the index does not take the value one. Because of these limitations, multi-lateral and multi-temporal comparisons are not possible using Törnqvist and Fischer indexes. However, a recent paper by the European Commission (2016) found, using the Fischer index, that TFP growth in the European Union (EU) has increased over time, albeit at a slower rate than in the past. While the growth rate surpassed 1% per annum between 1995 and 2005, it slowed to around 0,8% between 2005 and 2015. The European Commission states that labour productivity growth is the main reason for the TFP increase. Specifically, for Greek agriculture, TFP during 2005–2015 rose by 0,4% per annum.

If prices are not available, the most commonly applied index to compute changes in productivity is the Malmquist productivity index (MPI). (Coelli and Rao, 2005; Serrao, 2003; Domanska et al. 2014; Kijek et al., 2015; Rezitis et al., 2005; Galanopoulos et al., 2011; Latruffe et al., 2008). However, the DEA estimates of MPI are incomplete measures of productivity changes associated with changes in Scale (Grifell-Tatjé and Lovell, 1995; O'Donnell, 2012). Moreover, the DEA estimate of Malmquist indexes unreliably indicates unchanged productivity even if a firm can produce the same output using fewer inputs (O'Donnell, 2011).

The other indexes, namely the Hicks-Moorsteen TFP index (HMI) proposed by Bjurek (1996), and the Färe-Primont index (FPI) proposed by O'Donnell (2011), are used in constructing productivity indexes. However, between the two indexes, O'Donnell (2011) argues that the FPI is more reliable than HMI, as the former can be used to make reliable multi-lateral and multi-temporal comparisons. The HMI fails the transitivity test and thus can generally only be used to make a single binary comparison. FPI can be also applied without requiring data on prices. However, few applications of this index to the agricultural sector exist in the literature despite its attractive features.

In this article, FPI is applied as it is superior to the other TFP indexes. Khan, Salim and Bloch (2014) also used this methodology and found an average rate of 1,36% per annum in the broadacre Australian agriculture over the period 1990–2011. Laurenceson and O'Donnell (2014) estimated a rapid TFP growth over the period 1978 to 2010 in China's provinces. Rahman and Salim (2013) applied the FPI to compute TFP indices for agriculture in 17 regions of Bangladesh for the period 1948–2008. They found that the decline in technical

efficiency was the main cause of poor TFP growth. Le Clech et al. (2017) made a comparative analysis of the TFP estimations on the agricultural sector between the traditional Malmquist index and the new Färe-Primont index proposed by O'Donnell (2011). Dakpo et al. (2018) estimated an increase in TFP by 6,6% for a sample of French suckler cow farms in grassland areas during 1985–2014, with the technological progress being the major source of productivity. Islam et al. (2014) investigated farm businesses' profitability and productivity in the southwest of Western Australia using farm panel data over the period 1998–2008. The results indicated that productivity growth is similarly supported by technical change and efficiency gains. Tozer and Villano (2013) decomposed the productivity growth of a group of forty-five grain producers in Western Australia from 2004 to 2007 using O'Donnell's technique (2010). They show that producers are technical, mix and scale efficient. Input mix efficiency suggests that producers face some rigidity in their production decisions. However, output mix efficiency suggests that most producers adjust their output mixes to account for different seasonal conditions and enterprise mixes. Baležentis (2015) employed Färe-Primont indexes to estimate and decompose TFP changes of Lithuanian family farms. The results show that the technical efficiency was a decisive factor causing a decrease in TFP efficiency for crop and mixed farms. Baráth and Fertő (2017) investigated relative productivity levels and decomposed productivity changes for European agriculture between 2004–2013 using Färe-Primont indexes. The results suggest that TFP decreased slightly in the EU, with significant differences across member states. Specifically, for Greece, they found a -1,18% annual growth rate in TFP, which is due to the OSME deterioration by -1,92%. Kijek et al. (2019) used Färe-Primont indexes to measure changes in TFP of agriculture in 25 EU member states for the period 2004-2016. The results indicate that Spain, Greece and Italy have the highest TFP ranged from 0,6 to 0,7.

Regarding agricultural production in Greece, total output crops and crop production has decreased over the examined period (2004–2016). The highest decrease occurred in Central Greece, the Aegean Islands and Crete (region IV), where it dropped by 29%, followed by Thessaly (region III) by 24%, Epirus, Peloponnesus and the Ionian Islands (region II) by 16% and Macedonia and Thrace (region I) by 13%. As for total output livestock and livestock products, an increase by 29% is observed in region II, followed by a 5% growth in region III. On the contrary, livestock production for region I and IV dropped by 27% and 23%, respectively. Production in region I is concentrated in sheep and goats (19%), followed by cattle (14%) and mixed crops and livestock (11%). Region II produced mostly horticulture (29%), followed by other field crops (18%) and sheep and goats (11%). For region III, most agriculture production came from sheep and goats (31%), followed by other field crops and permanent crops combined (16%). As for region IV, mixed crops are most produced (23%), followed by orchards and fruits (13%) and sheep and goats (12%). The total utilized agricultural area (UAA) increased from 2004 to 2016. The highest growth occurred in region IV (91%), followed by region II (43%), region III (29%) and region I (9%). In addition to this, from 2004 to 2016 total labour was reduced. More specifically, labour dropped by 28% in region II, followed by 22% in region IV, 21% in region I and 13% in region III. On the contrary, there was growth in capital input by 92% for region II, 24% for region IV, 17% for region III and 13% for region I. Thus, the Greek farming sector moved from a labour-intensive to a capital-intensive sector. Finally, intermediate inputs such as seeds, fertilizer and feed for grazing stock for agricultural production grew only in region II (54%) and reduced in region III (-9%).

In the summer of 2007, a heatwave in Greece negatively affected the farming sector through numerous fires. 43% of the burned land was agricultural land causing a change in production technology. Based on the credit data of the Monetary Financial Institution (MFI), it is

recorded that from 2012 to 2017 there was a drop (13%) in private credit in the primary sector. To be more specific, in 2012 credit in the primary sector was 1628 million euros, where in 2016 it was 1341 million euros. More importantly, the percentage distribution of credit in the primary sector is only 1,7% in 2013 and 1,5% in 2016 (Bank of Greece, 2017). As for government expenditures on research and development (R&D), Greece spends too little (0,5% of the GDP). Greece has shown progress in innovation, despite the downturn in 2009–2010. The country’s innovation is growing, although at a lower rate than the rest of the EU (Karantininis, 2017). Furthermore, the share of Gross Fixed Capital Formation (GFCF) as a percentage of Gross Value Added (GVA) increased from 19% in 2004 to 21% in 2016, while GFCF declined by 19% from 2004 to 2016.

2. Methodology

In order to estimate the productivity indexes, we apply the Färe-Primont index (FPI). The FPI is free from restrictive assumptions about the nature of the production technology, a firm’s optimizing behavior, the structure of markets, returns to scale and/or price information. Moreover, FPI satisfies all other regulatory conditions of an index, such as multiplicative completeness and the transitivity test (O’Donnell, 2012). The above is a sufficient condition for decomposing a TFP index into measures of technical change (movements in the production frontier), technical efficiency change (movements of the units toward or away from the production frontier), scale efficiency and mix efficiency change (movements around the production frontier to capture economies of scope and scale) (Laureson and O’Donnell, 2014).

Productivity is defined by the OECD (2001) as the relationship between the volume of output and the volume of input used to generate that output. The productivity of a single-output single-input firm is almost always defined as the output-input ratio. Total Factor Productivity (TFP) is defined by O’Donnell (2008) in a concept of multiple-output multiple-input, by formally defining productivity to be the ratio of an aggregate output to an aggregate input.

Let $x_{it} = (x_{1it}, x_{2it}, \dots, x_{mit})$ and $q_{it} = (q_{1it}, q_{2it}, \dots, q_{mit})$ where q_{it} and $x_{it} \in \mathbb{R}^+$ are the vectors of inputs and outputs quantities (m) for firm i in period t. TFP is defined as (O’Donnell, 2008):

$$TFP_{it} = Q_{it}/X_{it} \quad (1)$$

where $Q_{it}=Q(q_{it})$ and $X_{it} = (x_{it})$ are the aggregate output and aggregate input respectively. The aggregator functions are non-negative, non-decreasing and linearly homogeneous.

O’ Donnell (2008) measures the overall productive efficiency of a firm as the ratio of observed TFP to the maximum TFP possible, using the available technology. He defines TFP efficiency (TFPE) as:

$$TFPE_{it} = TFP_{it}/TFP_{it}^* \quad (2)$$

Like Coeli and Rao (2005), this paper allows for technical progress and regress. Technical progress can be thought of as expansion in the production possibilities set coming, for example, from a scientific discovery. Conversely, technical regress can be narrowly conceptualized as contraction in the production possibilities set. O’Donnell (2010) states that technological regress is like “we forget the things we know”.

In this paper, technological change could be also defined as a measure of any changes in the external environment in which production takes place. Agriculture is strongly influenced by environmental factors such as climate and weather. These are exogenous variables that are physically involved in the production process but are beyond the control of the farm.

O'Donnell (2012a, 2012b) shows that equation (2) can be decomposed in several ways using various efficiency measures, such as:

$$TFPE_{it} = OTE_{it} \times OME_{it} \times ROSE_{it} \quad (3)$$

where OTE_{it} , OME_{it} and $ROSE_{it}$ denote measurements of output-oriented pure technical efficiency, mix efficiency and residual scale efficiency. Specifically:

- OTE , defined by Farell (1957), is the difference between the observed TFP and the maximum TFP possible using the existing technology, while holding the output mix, input mix fixed and the input level fixed.
- OME defines the pure mix efficiency, which is the difference between TFP at a technically efficient point for use of existing technology and the maximum TFP that is possible holding the input level fixed but allowing the output level and mix to vary.
- $ROSE$ measures the difference between TFP at a technical and mix efficient point and the maximum TFP that is possible through altering both input and output with existing technology (unrestricted production frontier).

The decomposition of equation (3) focuses on the part of firm efficiency, coming from a misallocation in the mix of outputs and scale efficiency appear then as a residual.

An alternative decomposition is also possible, as:

$$TFPE_{it} = OTE_{it} \times OSE_{it} \times RME_{it} \quad (4)$$

where OSE_{it} , RME_{it} denote measures of output-oriented scale efficiency and residual mix efficiency. Particularly:

- OSE defines the pure scale efficiency as the difference between TFP at a technically efficient point and the maximum TFP based on existing technology, while holding the input and output mixes fixed but allowing levels to vary.
- RME measures the difference between TFP at a technical and scale-efficient point and the maximum TFP possible through altering input and output mixes with existing technology (unrestricted production frontier).

The decomposition of equation (4) focuses on the part of firm efficiency, coming from a misallocation in the scale of outputs and mix efficiency appear then as a residual.

The last two terms of the previous two decompositions give the same value, which we denote by $OSME$ for output-oriented mix and scale efficiency, i.e.:

$$OSME_{it} = OME_{it} \times ROSE_{it} = OSE_{it} \times RME_{it} \quad (5)$$

- The output-oriented scale mix efficiency ($OSME$) measures the increase in TFP due to the movements from the technically efficient point to the point of maximum productivity.

These decompositions will allow us to identify the main source of productivity change in the Greek agricultural sector.

3. Sample and Data Description

The output and input qualities used in this empirical analysis are constructed from the Farm Accountancy Data Network (FADN or EU-DG AGR1). We use regional-level panel data covering the period 2004–2016. The study uses two outputs and five inputs.

- **Outputs**
 1. Total output crops & crop production (SE135).
 2. Total output livestock & livestock products (SE206).
- **Inputs**
 1. Total Labor Input (SE010) expressed in Annual Work Units (AWU).
 2. Total Utilized Agricultural Area (SE025). Land area that corresponds to the average arable land at the disposal of the farm and is calculated in hectares.
 3. Total Specific Costs (SE281) and Energy (SE345) are defined as Intermediate Inputs. Total Specific Costs consist of crop-specific inputs, such as seeds, seeding, fertilizer, crop protection products, and of livestock-specific inputs, such as feed for grazing stock and granivores.
 4. Total Livestock Unit (SE080). Livestock per farm converted into Livestock Units (LU).
 5. Capital input, defined as the sum of Buildings (SE450), Machinery (SE455) and Livestock (SE460).

According to FADN, Greece has been separated in four regions:

1. Macedonia and Thrace (Region I)
2. Epirus – Peloponnesus – the Ionian Islands (Region II)
3. Thessaly Region (III)
4. Central Greece – the Aegean Islands – Crete (Region IV)

All monetary values are deflated to real values (2015=100) prices using price indices. For outputs and inputs, the price index for agricultural products and the price index for the means of agricultural production are used respectively. Table 1 presents the descriptive statistics of all outputs and inputs over the period 2004–2016.

Table 1: Descriptive statistics

Region I				
Variable	Mean	Std. Dev.	Min	Max
Crop output	19324,31	1019,75	17432	20695
Livestock output	7202,73	1217,13	5131	9610
AWU	1,13	0,09	0,98	1,28
UAA	11,34	0,85	10,11	12,81
Inter. input	11296,29	615,04	10270	12256
LU	6,10	0,56	5,36	7,03
Capital input	39808,69	4091,33	33529	46670

Region II				
Variable	Mean	Std. Dev.	Min	Max
Crop output	16300,80	1794,74	13306	20488
Livestock output	6692,63	636,18	5845	7803
AWU	1,16	0,19	0,92	1,4
UAA	6,34	1,00	5,42	8,24
Inter. input	6459,16	745,65	5168	7947
LU	5,30	0,52	4,6	6,36
Capital input	24003,54	6688,80	16131	32434
Region III				
Variable	Mean	Std. Dev.	Min	Max
Crop output	19682,89	3066,16	16400	27547
Livestock output	7170,74	467,09	6255	8123
AWU	1,18	0,12	1,02	1,36
UAA	10,48	0,97	8,7	11,91
Inter. input	10485,63	513,58	9802	11468
LU	6,36	0,64	5,54	7,51
Capital input	31530,23	3512,58	26052	36339
Region IV				
Variable	Mean	Std. Dev.	Min	Max
Crop output	16804,77	2881,19	13251	23272
Livestock output	8122,60	1319,92	6514	10444
AWU	1,35	0,10	1,19	1,52
UAA	7,85	1,80	5,79	11,06
Inter. input	8024,23	518,25	7031	8787
LU	7,16	0,33	6,65	7,8
Capital input	28031,08	3279,24	23276	33207

4. Empirical Results

Table 2 presents the levels computed using the Färe-Primont analysis and their relative change from 2004 to 2016. Färe-Primont estimates are obtained under the assumption that the production technology exhibits Variable Returns to Scale (VRS) and that in any given period all farms have access to the same production possibilities set, which means that all farms must experience the same estimated rate of technical change. All TFP and efficiency measures reported in this section were computed using DPIN 3.0 software provided by the Center for Efficiency and Productivity Analysis (CEPA) at the University of Queensland in Australia. DPIN 3.0 software can also compute the components of equations (3) and (4).

The estimates of actual TFP in the first column of Table 2 reveal that in 2004 region III was the most productive and region II was the least productive. The difference in productivity between the two regions was 24%, which means that region II was 24% less productive than the third one. Region III remained the most productive region in 2016 as well, but in that year two regions were the least productive, region I and region IV. In addition to this, the difference in productivity between the most and the least productive regions has increased to 30%. It is noted that productivity decreased in all regions except region II, where TFP increased by 15%. The largest decrease (17%) in TFP is observed in the fourth region. Observing the TFP* change, it has declined by 6%, which is evidence of technical regression. The overall efficiency (TFPE) change is presented in the last column of Table 2. At first glance, results give mixed signals for each region. The second region has improved its efficiency, the third region is fully efficient and regions I and IV show a deterioration of efficiency.

Table 2: Level of Changes from 2004 to 2016

Region	TFP			TFP*			TFPE		
	2004	2016	Change	2004	2016	Change	2004	2016	Change
<i>I</i>	0,76	0,66	0,88	0,92	0,86	0,94	0,82	0,77	0,93
<i>II</i>	0,74	0,85	1,15	0,92	0,86	0,94	0,81	0,99	1,22
<i>III</i>	0,92	0,86	0,94	0,92	0,86	0,94	1,00	1,00	1,00
<i>IV</i>	0,79	0,66	0,83	0,92	0,86	0,94	0,86	0,76	0,88
<i>GREECE</i>	0,80	0,76	0,95	0,92	0,86	0,94	0,87	0,88	1,01

Finally, it is shown that TFP is affected by the 6% technical regression in all regions. Furthermore, it is noted that in region I both TFP* and TFPE affect the decrease in TFP. On the other hand, in region II, the improvement in TFPE is the only source of the increase in TFP. In region III, technical regression is the only factor of the decrease in TFP. In region IV, the main driver of the TFP decrease is the decrease in the overall efficiency.

The average for all of Greece is also presented in Table 2. At the country level, the TFP change from 2004 to 2016 is 95%. Hence, Greek agricultural productivity decreased by 5%. To be more specific, Greece in 2004 was 80% productive while in 2016 it was less productive (76%). It is also shown that there was no change in TFPE as $TFPE_{mean}$ is unity, indicating that technological regression decreased TFP. Technical regression can be attributed to the heatwave in Greece due to the fires in the summer of 2007. The phenomenon of technical regression in the Greek farming sector can also be supported on the grounds that the continuous decline of public investments and government expenditure on research and development (R&D) diversified the activities of farmers from high-value crops to low, risky

and less input-demanding crops. Hence, this restricted the outward movement of the frontier. Moreover, the low absorption (41%) of the Rural Development Funds did not enhance knowledge and innovation activities as it was expected. Additionally, during the period 2004–2014, ministers and deputies serving in the Greek Ministry of Rural Development and Food (GMRDF) changed very often. In the period 2004–2014, eight ministers took office, with an average term of 1,2 years. Three of these ministers held office for only a few months. (Karantininis, 2017). Moreover, based on the data of GMRDF, from September 2010 to September 2015, there were more changes in ministers of GMRDF. Specifically, there have been six ministers in office, of which four held office for less than a year.

The output-oriented efficiency decomposition is reported in Table 3, indicating that all regions were fully technically efficient in 2004 and 2016, with the exception of region IV, where technical efficiency dropped slightly, by 2%, in 2016. It is known from methodology (eq. 5) that TFPE can be decomposed in OTE and OSME. Hence, this implies that OSME change is equal with TFPE change for the first three regions. This indicates that for region I and II production efficiency is affected by any change in input and output mix solely. For region I and IV, scale and mix efficiency reduced by 7% and 10%, respectively, which means these regions adjusted scale and scope production less optimally in 2016 relative to 2004. On the other hand, for region II, the input-output mix improved in 2016 as the OSME change increased by 22%. As it was reported in the Table 2 analysis, region III was fully efficient in both 2004 and 2016.

Table 3: Output-Oriented Components of Efficiency Change

<i>Region</i>	TFPE			OTE			OSME		
	2004	2016	Change	2004	2016	Change	2004	2016	Change
<i>I</i>	0,82	0,77	0,93	1,00	1,00	1,00	0,82	0,77	0,93
<i>II</i>	0,81	0,99	1,22	1,00	1,00	1,00	0,81	0,99	1,22
<i>III</i>	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
<i>IV</i>	0,86	0,76	0,88	1,00	0,98	0,98	0,86	0,77	0,90

Table 4 reports the estimated average annual rates of growth in the productivity, technological change and efficiency of agriculture in three sub-periods: 2004–2008, before the economic crisis period; 2008–2011, the first years of the economic crisis; and 2011–2016, the most recent examined years. With no surprise, the average annual rates of the whole period reflect the results of Table 2. The TFP of region IV decreased the most, by 1,55% per annum, while only the second region experienced a positive 1,18% per annum productivity growth. This growth is due to the 1,69% per annum increase in efficiency. The technological change dropped slightly, by 0,51% per annum.

Table 4: Average Annual Rates of Growth* in the TFP index and efficiency

Region	2004–2008			2008–2011			2011–2016			2004–2016		
	TFP	TFP*	TFPE	TFP	TFP*	TFPE	TFP	TFP*	TFPE	TFP	TFP*	TFPE
I	3,60%	-1,25%	4,85%	-6,22%	-	-0,31%	1,73%	3,33%	-5,07%	-1,08%	-0,51%	-0,57%
II	-0,29%	-1,25%	0,96%	-1,21%	-	4,70%	3,79%	3,33%	0,46%	1,18%	-0,51%	1,69%
III	-5,75%	-1,25%	-4,50%	-0,11%	-	5,81%	3,44%	3,33%	0,11%	-0,51%	-0,51%	0,00%
IV	-1,20%	-1,25%	0,05%	-0,95%	-	4,97%	-	2,19%	-5,52%	-1,55%	-0,51%	-1,04%
GR	-0,91%	-1,25%	0,34%	-2,12%	-	3,79%	0,83%	3,33%	-2,50%	-0,49%	-0,51%	0,02%

* $\ln(dTFP_{2016}/dTFP_{2004})/(2016-2004)$

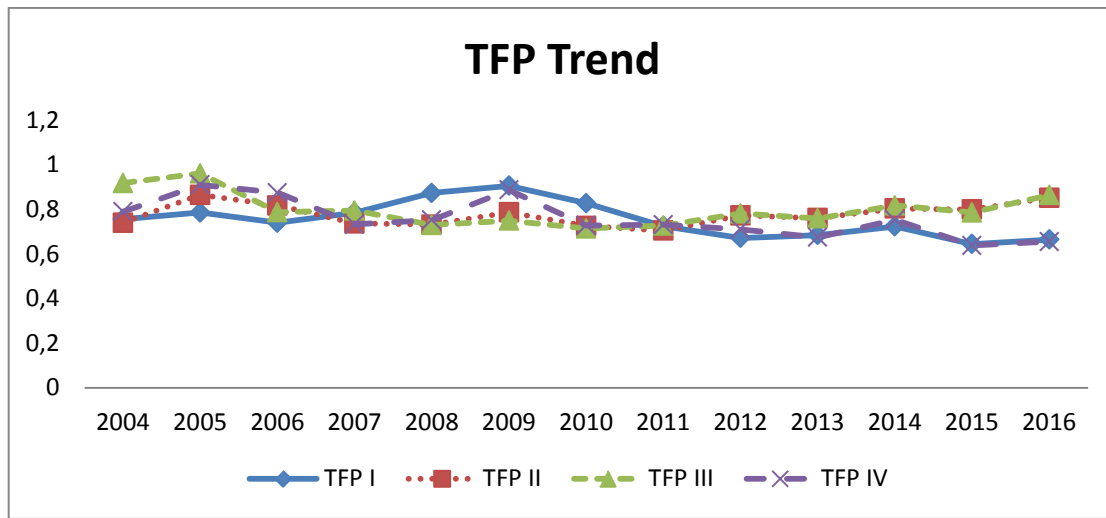
In the first period (2004–2008), it is worth mentioning that there is a large increase in the TFP of the first region, by 3,6% per annum. As the TFP* annual rate dropped by 1,25% per annum, the TFP increase, by 4,85% per annum, came from the efficiency growth. However, the third region experienced a large decrease in TFP, by 5,75% per annum, mostly due to overall inefficiency. As for the second sub-period (2008–2011), there was a major decrease in TFP* by 5,92% per annum. This indicates that from 2008 to 2011 there was a high technical regression. This had a negative impact on TFP, mostly for the first region, where the annual average rates dropped by 6,22% per annum. However, the other regions also had major increases in efficiency; therefore, TFP in regions II, III and IV decreased much less compared with the drop in region I. The last sub-period (2011–2016) is the only period where technical progress is observed, where the average annual rate increased by 3,33%. In the second and third regions, the average rate of TFP growth was 3,79% and 3,44% per annum, respectively, due to technical progress. On the other hand, the deterioration of efficiency in the first and fourth regions resulted in a TFP decrease.

On average, the slowdown of TFP growth in Greek agriculture, by 0,5% per annum in the examined period, has been mainly affected by technological regression, by 0,5% per annum. However, the positive TFP growth, by 1,18% per cent per annum, in the second region could be attributed to the high efficiency increase right after the economic crisis. Finally, the TFP annual drop for region I is mainly due to the major deterioration of efficiency, by 5,07% per annum in 2011–2016, and of the technical regression in 2008–2011.

Comparable information with our results regarding TFP of Greek agriculture can be found in Barath and Fertő, (2017) and in Kijek et al., (2019). Barath and Fertő's findings show that TFP for Greece decreased significantly by 11%, for Italy by (-4%), for Portugal by (-3%) and except for Spain an increase by 8% for the period 2004-2013 using Färe-Primont indexes. Kijek et al.'s (2019) results for 25 EU countries in 2004-2016 using Färe-Primont indexes indicate a significant decrease of 14% for Greece, (-3%) for Italy and (+17%) for Spain. Our findings regarding Greece should be interpreted and compared with the above studies with caution because even though they use the same methodology, data source is different (Eurostat). It should also be mentioned that we calculate the TFP for Greece as the mean average of the regions and not using aggregate data for Greek agriculture as the above applications do. All the above studies confirm the slowdown of the TFP for Greek agriculture which is in line with our results. However, in the "CAP context indicators (2019-2020)" of the European Commission, updated in 2018, the TFP of the agricultural sector for the EU states is estimated as a 3-year moving average for 2007-2017. A positive average annual change in TFP is recorded for almost all states. Indicatively, for Greece 0,4%, Spain 1,7%, Portugal 1,7% and Italy 0,6%.

Figure 1 presents the Färe-Primont estimates of the TFP of agriculture in Greek regions. In Appendix A at the end of the paper, the measures of TFP and efficiency components for all regions are presented. It is observed that the trend of TFP in region III from 2008 to 2016 is almost identical to region II. This similarity in the movement of TFP is because efficiency has the same trend in both regions (Tables 2A and 3A in Appendix A). In addition to this, productivity in regions II and IV, from 2004 to 2007, behaves the same way. In 2005, regions II, III and IV reached their highest TFP levels. Moreover, from 2011 to 2016, regions I and IV behave the same in terms of productivity.

Figure 1: Färe-Primont estimates of the TFP



It is observed that, on average, the first region is 75% productive (Table A1, Appendix A). The highest value of TFP (0,91) was in 2009. In this year, region I was fully efficient, so the productivity was equal to maximum TFP using the technology available. The least productive year was 2015, as region I was only 64% productive. This was the year where there was technical regression and deterioration of overall efficiency. The average tendency of the examined period in TFP is given by the mean. As mentioned before, region I was 75% productive in all the years examined due to 10% inefficiency, and also maximum TFP using the technology available was below unity ($TFP^*_{mean}=0,84$). As for the analysis of efficiency change, OTE is equal to unity in the whole examined period. This shows that pure technical efficiency has been achieved. In other words, the point that represents the production of the holdings is located on the production frontier. It is also implied that any overall efficiency change comes solely from the scale and mix effect (OSME). The OSE value is also unchanged and equal to one from 2004 to 2016, since maximum levels were reached in both these years. Thus, with a constant output mix, region I reached Constant Returns of Scale (CRS), meaning Mix Invariant Optimal Scale (MIOS) is achieved. The only exceptions are in 2005 and 2012 where OSE and OME are below unity. The most efficient period for region I was from 2008 to 2011. In these years, the farms worked fully efficiently. More specifically, region I achieved pure technical efficiency and also adjusted the input and output mix optimally. It is also implied that all the efficiency components were equal to unity. However, this was not the case from 2013 onwards, where there was a downward trend in OSME. There was also a high deterioration of TFPE from 2014 to 2016. The most inefficient year for the agricultural sector of region I was 2016, in which it was only 77% efficient. In order for the farms be fully efficient, reform in at least one output and at least one input is needed. The $TFPE_{mean}$ is equal to 0,90, meaning that the average inefficiency in the examined years is 10%. Not surprisingly, the inefficiency comes from OSME ($OSME_{mean}= 0,90$) while on average region I is fully technically efficient.

In region II, there was a 15% increase in productivity from 2004 to 2016. The highest level of productivity occurred in 2005 and the lowest in 2011. Region II is the only region where TFP from 2004 to 2016 increased. Nevertheless, Table A2 shows that TFP is less than one in all years. From 2014 onwards the TFP increased, reaching its highest level in 2016. It is also shown that, in this period, region II was almost fully efficient. Also, there is technological progress, as TFP^* increased by 7,5% compared with 2015. Furthermore, like region I, region

II also achieved pure technical efficiency in all years. The same applies in OSE and OME, respectively, meaning that any change in overall efficiency is solely due to a change in OSME. Again like region I, the second region works in the production frontier, with a CRS in the constant output mix restriction. From 2008 to 2010 the efficiency levels are low compared with the other years. However, from 2012 onwards, full efficiency was almost achieved. This is exactly the opposite of the first region's efficiency trend. In 2013 and 2015, all efficiency components are equal to unity, meaning that farms worked fully efficiently. It is known that OTE was at unity in all years, like the previous region, so, again, the 7% inefficiency came from scale and mix misallocations ($OSME_{mean}=0,93$).

In 2005, region III reached its highest TFP level. In this year, region III was fully efficient and then TFP achieved its maximum level. It is also implied that the level of TFP* is equal to TFP as TFPE is at unity. The lowest level occurred in 2010, in a period of inefficiency, where region III was 71% productive. Compared to other regions, region III achieved the highest level of TFP. It is shown that, like region II, the third region's TFPE was also affected by the economic crisis as efficiency deterioration exists from 2008 to 2010. In these years, OTE and OSME decreased. This means that the point that represents the production shifted below the production frontier and that an adjustment in input and output mix was also needed. Like the second region, efficiency recovered in 2012 onwards, achieving full efficiency. Region III behaved the same way as region II in terms of efficiency. Finally, on average, region III was only 5% inefficient. Furthermore, pure technical efficiency is almost achieved, with OTE_{mean} equal to 0,99. The $OSME_{mean}$ is also really high, equal to 0,96. It is worth mentioning that the highest efficiency levels on average are presented in the third region.

In region IV, the lowest productivity level was recorded in 2015, at only 64% productivity. The main reason for this drop is that inefficiency and technological change greatly decreased. In 2015 and 2016, region IV farms did not operate in the production frontier as OTE was less than unity. OTE dropped by 4% from 2014 to 2015, which signifies that production shifted below the production frontier. The TFPE trend is also worth mentioning as it seems to be more volatile compared with the other regions. The highest efficiency scores occurred in 2006 and 2011, when the farms were fully efficient and maximum TFP was achieved. The mean of the indexes indicates that in the examined period the fourth region was 75% productive and 10% inefficient due to OSME.

5. Conclusion

The aim of this article has been to provide estimates of TFP in four regions of Greece using recent developments in the index theory on multiplicative-complete economically ideal productivity indexes and their decomposition into a measure of technical change and measures of efficiency change including pure technical efficiency change, mix efficiency change and scale efficiency change. The empirical analysis is based on the use of Färe-Primont, which was defined by O'Donnell (2011) and which belongs to the category of multiplicative-complete economically ideal productivity indexes. The analysis is carried out on a panel of four Greek regions over the period 2004–2016.

The results reveal that in Greek agriculture TFP diminished at an average rate of 0.49% per annum or by 5% from 2004 to 2016. On average, TFP in all regions are below unity. Thus, Greek farming sector uses more inputs than necessary for the agricultural production. The contribution of total factor productive efficiency is negligible, estimated at 0.02% per annum, due to the decline and stagnancy in efficiency levels in most of the regions. This result of TFP falling is mainly due to the effect of 0.51% per annum decreases in technical change

during the sample period. This technical regression in Greek agriculture could be associated with environmental factors (such as the fires and the heatwave in 2007) and/or changes in technical knowledge (a result of the low spending on R&D, of almost 0.5% of GDP). Furthermore, a 13% decrease in private credit in the primary sector is recorded from 2012 to 2017. However, it is worth mentioning that during the last two years (2014–2016) Greek agriculture experienced technical progress, which is the reason for the increases in TFP for region II and region III by 6% and 5%, respectively, being at the same time fully efficient. To the contrary, regions I and IV faced TFP declines by 8% and 12%, respectively, because the technical progress did not offset the deterioration in overall efficiency.

In particular, only region II experienced growth in TFP, by 15% or 1.18% per annum, over the examined period. This was due to the significant increase (improvement) in overall efficiency, by 22% or 1.69% per annum. The remaining regions (I, III and IV) show TFP decreases by 12%, 6% and 17%, respectively. The highest decrease of TFP in region IV is mainly due to the deterioration of scale and mix efficiency by 12%. Thus, to increase TFP, region IV will need to change at least one input and at least one output. However, region III is the most efficient region and has consistently the highest TFP level, so that its experience defines the frontier of production possibilities over all regions. Furthermore, the decrease in TFP is mainly due to technical regression because of stagnancy in overall efficiency. In region I, technical change and efficiency change are equally important in affecting TFP decreases. The results also show that all regions were technically fully efficient and produced at the optimal scale ($OTE=OSE=1$) during the sample period. The TFP trend in regions II and III is almost similar and region I and IV follow the same trend from 2011 to 2016.

Finally, on average, the deterioration in TFP during 2004–2016 is the result of the large decrease (2.12% per annum) in TFP during the first three years of the economic crisis (2008–2011); thereafter TFP started increasing by 0.83% per annum. Overall, the results show that technical change is the main component that explains a significant part of the decline in TFP in Greek agriculture. The need for increased investment in R&D is unquestionable as it would improve technical change. Besides, Greece should support and exploit the agricultural European Innovation Partnership (EIP–AGRI). EIP–AGRI works to foster competitive and sustainable farming and forestry that ‘achieves more and better from less’. The EIP–AGRI brings together innovation actors (farmers, advisers researchers, businesses NGOs and others) at EU level and within the rural development programmes (RDPs). Together they form an EU–wide EIP network. EIP Operational Groups can be funded under the RDPs, are project–based and tackle a certain (practical) problem or opportunity which may lead to an innovation.

Appendix A

Table A1: Measures of TFP and efficiency components—Macedonia and Thrace (I)

YEAR	TFP	TFP*	TFPE	OTE	OSME	OSE	OME	RME	ROSE
2004	0,76	0,92	0,82	1,00	0,82	1,00	1,00	0,82	0,82
2005	0,79	0,96	0,82	1,00	0,82	0,97	0,89	0,85	0,92
2006	0,74	0,87	0,85	1,00	0,85	1,00	1,00	0,85	0,85
2007	0,79	0,79	0,99	1,00	0,99	1,00	1,00	0,99	0,99
2008	0,87	0,87	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2009	0,91	0,91	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2010	0,83	0,83	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2011	0,72	0,73	0,99	1,00	0,99	1,00	1,00	0,99	0,99
2012	0,67	0,78	0,86	1,00	0,88	0,98	0,98	0,89	0,89
2013	0,68	0,76	0,90	1,00	0,90	1,00	1,00	0,90	0,90
2014	0,72	0,82	0,89	1,00	0,89	1,00	1,00	0,89	0,89
2015	0,64	0,80	0,81	1,00	0,81	1,00	0,93	0,81	0,87
2016	0,66	0,86	0,77	1,00	0,77	1,00	1,00	0,77	0,77
G. MEAN	0,75	0,84	0,90	1,00	0,90	1,00	0,98	0,90	0,91

Table A2: Measures of TFP and efficiency components—Epirus, Peloponnesus and the Ionian Islands (II)

YEAR	TFP	TFP*	TFPE	OTE	OSME	OSE	OME	RME	ROSE
2004	0,74	0,92	0,81	1,00	0,81	1,00	1,00	0,81	0,81
2005	0,86	0,96	0,90	1,00	0,90	1,00	1,00	0,90	0,90
2006	0,82	0,87	0,93	1,00	0,93	1,00	1,00	0,93	0,93
2007	0,74	0,79	0,93	1,00	0,93	1,00	1,00	0,93	0,93
2008	0,73	0,87	0,84	1,00	0,84	1,00	1,00	0,84	0,84
2009	0,79	0,91	0,87	1,00	0,87	1,00	1,00	0,87	0,87
2010	0,73	0,83	0,88	1,00	0,88	1,00	1,00	0,88	0,88
2011	0,71	0,73	0,96	1,00	0,96	1,00	1,00	0,96	0,96
2012	0,77	0,78	0,99	1,00	0,99	1,00	1,00	0,99	0,99
2013	0,76	0,76	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2014	0,80	0,82	0,98	1,00	0,98	1,00	1,00	0,98	0,98
2015	0,80	0,80	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2016	0,85	0,86	0,99	1,00	0,99	1,00	1,00	0,99	0,99
G. MEAN	0,78	0,84	0,93	1,00	0,93	1,00	1,00	0,93	0,93

Table A3: Measures of TFP and efficiency components—Thessaly (III)

YEAR	TFP	TFP*	TFPE	OTE	OSME	OSE	OME	RME	ROSE
2004	0,92	0,92	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2005	0,96	0,96	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2006	0,79	0,87	0,90	1,00	0,90	1,00	1,00	0,90	0,90
2007	0,79	0,79	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2008	0,73	0,87	0,84	0,96	0,87	0,97	0,97	0,90	0,89
2009	0,75	0,91	0,83	0,97	0,85	0,93	0,91	0,91	0,93
2010	0,71	0,83	0,86	1,00	0,86	1,00	1,00	0,86	0,86
2011	0,73	0,73	0,99	1,00	0,99	1,00	1,00	0,99	0,99
2012	0,78	0,78	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2013	0,76	0,76	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2014	0,82	0,82	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2015	0,79	0,80	0,98	1,00	0,98	1,00	1,00	0,98	0,98
2016	0,86	0,86	1,00	1,00	1,00	1,00	1,00	1,00	1,00
G. MEAN	0,80	0,84	0,95	0,99	0,96	0,99	0,99	0,96	0,96

Table A4: Measures of TFP and efficiency components—Central Greece, the Aegean Islands and Crete (IV)

YEAR	TFP	TFP*	TFPE	OTE	OSME	OSE	OME	RME	ROSE
2004	0,79	0,92	0,86	1,00	0,86	1,00	1,00	1,00	0,86
2005	0,91	0,96	0,95	1,00	0,95	1,00	1,00	1,00	0,95
2006	0,87	0,87	1,00	1,00	1,00	1,00	1,00	0,90	1,00
2007	0,73	0,79	0,92	1,00	0,92	1,00	1,00	1,00	0,92
2008	0,75	0,87	0,86	1,00	0,86	0,97	1,00	0,90	0,86
2009	0,89	0,91	0,98	1,00	0,98	0,93	1,00	0,91	0,98
2010	0,73	0,83	0,88	1,00	0,88	1,00	1,00	0,86	0,88
2011	0,73	0,73	1,00	1,00	1,00	1,00	1,00	0,99	1,00
2012	0,71	0,78	0,91	1,00	0,91	1,00	1,00	1,00	0,91
2013	0,67	0,76	0,89	1,00	0,89	1,00	1,00	1,00	0,89
2014	0,75	0,82	0,92	1,00	0,92	1,00	1,00	1,00	0,92
2015	0,64	0,80	0,80	0,96	0,83	0,97	1,00	0,98	0,83
2016	0,66	0,86	0,76	0,98	0,77	0,96	0,91	1,00	0,85
G. MEAN	0,75	0,84	0,90	1,00	0,90	0,99	0,99	0,96	0,91

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