International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 8, No. 2, 2020, pp. 167-178

TOTAL FACTOR PRODUCTIVITY CHANGE IN GREEK CROP PRODUCTION USING A FARE-PRIMONT INDEX ANALYSIS

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Abstract

This paper investigates the total factor productivity (TFP) in Greek crop farms. The Farm Accountancy Data Network (FADN) is used as a resource which considers eight types of farming and covering the period 2004-2017. The Färe-Primont indices are employed to estimate total factor productivity change and to determine and explain the changes in its technology and efficiency ellements. It also compares changes in 2004-08, 2008-13 and 2013-17 sub-periods, since after 2008 Greece has experienced the economic crisis. Farms experience great technological regress of 11% or at an average rate of 0.81% annually. In addition, growth rates of TFP and efficiency are presented over the sub-periods. The results do indicate a decrease in TFP by 3% or at an average rate of 0.25% annually for crop farming during 2004-2017. COP and olive farms have the highest TFP increase, 18% and 19% respectively while permanent crops have the lowest (4%). Further the results demonstrate that on average, the technical regress (11%) results in a 3% reduction in Greek crop production which prevails the improvement in overall efficiency by 6%.

Key words: *Total factor productivity (TFP); Färe-Primont Index; crop production; technical efficiency; scale and mix efficiency*
JEL Codes: *C43;O47;Q12*

1. Introduction

Conventionally, assessing a sector's competitiveness has relied on calculating Total Factor Productivity (TFP) growth, which is the proportion of the output growth rate to the input growth rate. In farming, TFP growth is used as a barometer to assess how well a farm can produce income and factor employment levels, under competition pressure both at home and from abroad. Thus TFP growth is necessary to help a country's farming sector endure domestic and international competitive stress.

An rise in TFP indicates an increase in the amount of output that is not a result of a hike in inputs. TFP discloses the results of several components, like new technology, boosts in efficiency, economies of scale, leadership ability, and changes in production.

Empirical studies on technical efficiency and TFP analysis in agriculture have been increasingly attracted a great attention for two main reasons: first, productivity significantly affects food security and food prices and, second, productivity is crucially linked to the use of natural resources and factor reallocation to the non-agricultural divisions of the economy. Higher value added can be achieved in other economic activities by improving performance and capacity through the release of the production factors (O'Donnell, 2010). In addition, productivity is the key driver of competitiveness in the long-run (European Commission, 2009). Therefore, employing better technology and using inputs more efficiently provide gains in TFP that result in lower input (or higher output).

The European Commission has started a bold new program in Europe that aims at conserving resources through their more effective use, calling on the agricultural sector to do “more with less” in 2020. This is also supported by the “*European Innovation Partnership Agricultural productivity and sustainability*” where farmers are faced with the challenge to produce “more and better from less” (European Commission, 2017). Additionally, TFP is one among the context indicators for CAP 2014-2020.

There are several indices that can be used to calculate the change in TFP; however, they are not equally robust or dependable. If input and output prices are known, indices such as Paasche, Laspeyers, Törnqvist and Fisher can be computed. Otherwise, if prices are not available, Malmquist and Hicks-Moorsteen indices, which depend on distance functions, can be used. But, these indices do not pass the transitivity axiom meaning that multilateral and multi-temporal comparisons are not feasible which are at the interest of most empirical studies (O’Donnell, 2011a). At the same time, Lowe, Färe-Primont, and geometric Young indices are satisfactory for such comparisons. In addition, Färe-Primont index (FPI) depends on distance functions and needs no price information.

In relation to the other TFP indexes, the FPI is preferable because it can be decomposed into three factors of productivity change namely: “*technical change (movements in the production frontier), efficiency change (movements of the units towards or away from the production frontier), and scale-mix efficiency change (movements around the production frontier to capture economies of scope and scale)”* (Laurenceson & O’Donnell, 2014). Typically, government policies bring about identified consequences to the specific components of productivity change. In this way, we can trace the actions of government and their impacts for policy implementation. Therefore, government policies should aim at these specific factors to increase farming productivity. For instance, R&D would probably technology in farming, education and training programs would assist with understanding and implement “best practices”, and taxes and subsidies would enhance efficiencies of scale.

Despite its interesting features, the FPI has not been used empirically in agriculture (Rahman & Salim 2013; Tozer & Villano 2013; Islam et al. 2014; O’Donnell 2014; Khan et al. 2014; Baležentis 2014; Baráth & Fertő 2017; Dakpo et al., (2017, 2018); Le Clech & Fllat Castejón, 2017).

The primary aim of this study is to determine the change of the TFP in the Greek agricultural sector from 2004 to 2016. In doing so, the FPI is computed without price data. As far as I know no other studies use the FPI to calculate TFP change in the Greek crop farming. However various studies have estimated technical efficiency for the Greek sheep farms (Fousekis et al. 2001; Theocharopoulos et al. 2007), for pig farming (Galanopoulos et al.2006) and for the Greek agriculture (Rezitis et al. 2002).

2. Outlook of the Greek Agricultural Sector

The importance of Greece’s agricultural sector to the total economy is shown in terms of the share of agricultural value added in GDP, which has dropped from 4.3% in 2004 to 3.7% in 2017, as agricultural gross value added and GDP have decreased by 19% and 7% during the same period (EUROSTAT). In addition the participation of the agricultural output to the GDP remained the same to 6.5% during the examined period due to the decrease in GDP by 7% while the output decreased by 3%. Employment in agriculture (as % of total employment) was reported at 11% in 2017 according to Hellenic Statistical Authority following a decrease of 15% since 2004. These results show that the sector has been less essential for the economy due to the financial crisis (2008-today).

Over the examined period (2004-2017), Greek agriculture has moved into a continuously changing political environment characterized by a radical change of the 2003 CAP that was implemented in 2006, the wide range of regulations that have followed since 2008 with the socalled "health check" of CAP, and also the new major reform of 2013 which, after a transitional year, entered into force in 2015 and applies to the new CAP 2014-2020.

In 2017 Greece ranks ninth in the EU-28 in terms of total agricultural output (€ 10 billion in 2017) contributing 2.6% of EU-28 which has decreased by 12% since 2004 with a decrease of 14% in crop output and a smaller decrease of 7% in animal output. This change results in the relationship between crop and animal production changing from (70/30) in 2013 to (75/25) in 2017, while in the EU-28 the corresponding ratio is 43/57. This unequal proportion that prevailed in 2000 is still one of the structural problems of Greek agriculture today.

Intermediate consumption increased significantly by 24% since 2004 and accounted for a high share (52% - in 2017) of the total output value The highest cost of inputs (60%) is covered by feed (39%) and energy and lubricants (22%). As a result of the crisis, there was a significant reduction in gross fixed capital formation (mainly in machinery and equipments) by 20% during the period 2004-2017.

In 2016 the utilized agricultural area was 4.5 m. hectares with an increase of 14% between 2005 and 2016. However, in the same period, the number of agricultural holdings was decreased by 18%. This structural change resulted in the increase of the average size of holdings from 5 hectares in 2005 to 7 hectares in 2016. Indicatively, it is noticed that the area of vineyards and COP increased by 16% and 7% respectively while their holdings decreased by 1% and 7% respectively. The highest decreases in holdings were in mixed crops by 47%, field crops by 35%, permanent crops by 31%, horticulture by 25% and fruits by 16%. Olive holdings suffered by small reductions of 3%. Similarly, high decreases occurred in the area of mixed crops, permanent crops and horticulture by 41%, 35% and 34% respectively.

Greek agriculture is dominated by relatively small farms, mainly family-run holdings (less than 2 hectares), which constitute 6.5% of the total utilized agricultural area. On the other hand, the largest farms (> 100 hectares) constitute 34% of the total utilized agricultural area having faced a large decrease in their number by 27% and in their cultivated area by 19% from 2010 to 2016. These farms cover a very large part of land leaving only very little land for smaller holdings.

According to Eurostat figures, in 2017 labor force in agriculture expressed thousand persons was estimated at 438 having recorded a decrease of 15% since 2004.

In 2017 crop output accounted for 75% of the total agricultural goods whereas crop production decreased by 6% since 2004. The main agricultural products as a percentage of total crop value are fruits (28%),vegetables and horticultural products (23%) industrial crop (11%), cereals (9%), grapes (5%) and olives (3%). However, a sharp drop (16%) of cereals production has been followed since 2004 with an emphasis on reducing production of durum wheat (25%) and maize (34%). Substantial increases occurred in the production of rape and sunflower from 32.45 thousand tonnes in 2004 to 254.14 thousand tonnes in 2017. Small increases recorded in permanent crops and fruits production by 6% and 8% respectively. During the examined period, grapes for wine have recorder a decrease of 8% while the production of grapes for table use has doubled. Olive groves for oil production occupy the bulk of crops (865 thousand hectares) showing a significant increase of 17% in their area.

3. Methodology

In the event of *a multiple-input, multiple-output firms* O'Donnell (2010) defines TFP as:

$$TFP_{nt=}\frac{Q_{nt}}{X_{nt}} \tag{1}$$

where $Q_{nt}=Q(q_{nt})$ is an aggregate output, $X_{nt}=X(x_{nt})$ is an aggregate input, and Q(.) and X(.) are nondecreasing linearly homogeneous aggregator functions. According to this definition the index number that compares the TFP of firm *n* in period *t* with the firm *m* in period *s* is:

$$TFP_{ms,nt} = \frac{TFP_{nt}}{TFP_{ms}} = \frac{Q_{nt}/X_{nt}}{Q_{ms}/X_{ms}} = \frac{Q_{ms,nt}}{X_{ms,nt}} \qquad (2)$$

where $Q_{ms,nt}$ is an output quantity index and $X_{ms,nt}$ is an input quantity index. Equation (2) expresses TFP change as a measure of output index growth divided by an input index growth (O'Donnell, 2010).

According to O'Donnell (2011) "*if $D_0(.)$ and $D_t(.)$ are output and input distance functions which are nondecreasing, nonnegative and linearly homogeneous the aggregator functions can be expressed as:*

$$Q(q) = D_0(x_0, q, t_0) \qquad (3)$$
$$X(x) = D_1(x, q_0, t_0) \qquad (4)$$

where q and x are vectors of output and input quantities respectively".

Then if (3) and (4) are substituted into (2) they give rise to the Färe-Primont TFP index:

$$TFP_{ms,nt} = \frac{D_0(x_{0,}q_{nt,}t_0)D_1(x_{ms}, q_0, t_0)}{D_0(x_{0,}q_{ms,}t_0)D_1(x_{nt}, q_0, t_0} \qquad (5)$$

According to O'Donnell (2011b) the Färe-Primont index is economically-ideal as it satisfies all economically–relevant axioms and tests from index numbers theory, including an identity axiom and a transitivity test. This implies that it can be used to make reliable multi-temporal (i.e., many period) and/or multi-lateral (i.e., many firms) comparisons of TFP and efficiency.

According to O'Donnell (2008) the overall productive efficiency ($TFPE_t$) for a firm *i* in period *t* is defined by the ratio:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_{it}^*} \qquad (6)$$

where, TFP_{it} denotes the highest TFP possible using any technically feasible inputs and outputs. Multiplicative-complete TFP indexes can be conveniently decomposed by rearranging equation (6) as $TFP_{it} = TFP^*_{it} \times TFPE_{it}$. A similar equation holds for firm *h* in period *s*. Thus, the TFP index defined by (2) can be written (O'Donnell, 2012b):

$$TFP_{hs,it} = \frac{TFP_{it}}{TFP_{hs}} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{TFPE_{it}}{TFPE_{hs}}\right) \qquad (7)$$

The first term in parentheses is a measure of the difference in the maximum TFP possible in the two periods-this is a natural measure of technical change. Equation (7) reveals that TFP change can be exhaustively decomposed into a measure of technical change and a measure of efficiency change. However, O'Donnell' (2008) defined the following decompositions:

$$TFPE_t = OTE_t \times OME_t \times ROSE_t \qquad (8)$$
$$TFPE_t = OTE_t \times OSE_t \times RME_t \qquad (9)$$

where, OTE_t is "*output-oriented technical efficiency*" defined by Farrell (1957) defined by the difference between 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_t is pure output-oriented mix efficiency defined by 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, $ROSE_t$ is residual output-oriented scale efficiency defined by the difference between TFP at a technically and mix efficient point and the maximum TFP that is possible through altering both input and output with existing technology and RME_t is residual mix efficiency defined by the difference between TFP at a technically and scale-efficient point and the maximum TFP possible when input and output mixes (and levels) can vary.

Then any multiplicatively-complete TFP index can be separated into measures of technical change, technical efficiency change and a combination measure of scale and mix efficiency change (O'Donnell, 2012a). So equations (7), (8) and (9) can be used to once again separate the efficiency change component into a specific number of meaningful measures:

$$TFP_{hs,it} = \frac{TFP_{it}}{TFP_{hs}} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{OTE_{it}}{OTE_{hs}}\right)\left(\frac{OSME_{it}}{OSME_{hs}}\right) \qquad (10)$$

where $OSME_{it}=OSE_{it}\times RME_{it}$ denotes output-oriented *ecale-mix efficiency*[1]. The output-oriented scale-mix efficiency measures the increase in TFP between a technically efficient point with the observed scale and input mix to the point of maximum productivity.

Following O'Donnell (20008, 2010, 2011b, 2012) the Färe-Primont productivity index is computed together with the various components of equation (10) using the computer program DPIN3.0 (O'Donnell, 2011a).

4. Data

The farm-level data taken from the Farm Accountancy Data Network (FADN) between 2004 and 2017. Our farm type classification follows the TF14 grouping. Types of farming are defined in terms of total standard output. Eight out of fourteen types of farming are subject to our analysis due to data availability. These are the following (EU FADN database code in brackets):

- Specialist CłOP (TF15)
- Specialist other fieldcrops (TF16)
- Specialist horticulture (T20)
- Specialist wine (TF35)
- Specialist fruits (TF36)
- Specialist olives (TF37)
- Permanent crops combined (TF38)
- Mixed crops (TF60)

For the analysis one single output and four inputs are used. The selected variables from the FADN database are the following:

- Total value of output in Euros (SE131)
- Labour input in Annual Working Units, AWU corresponds to 2,200 hours, (SE010)
- Land, Utilised Agricultural Area in hectares (SE025)

[1] For graphic illustration of the index numbers specified in equations (7-10) can be found in O'Donnell (2010, 2011).

Table 1. Descriptive statistics of the Greek FADN samples used over the period 2004-2017

	Min	Max	Mean (μ)	Standard deviation
COP				
Output	17131	22565	19838	1820
UAA	16.01	21.55	18.34	1.46
Labour (AWU)	0.53	0.73	0.63	0.06
Intermediate consumption	6096	7725	6741	514
Depreciation	3075	4557	3977	422
FIELD CROPS				
Output	22371	32877	25330	3078
UAA	10.55	14	12.85	1.11
Labour (AWU)	0.93	1.25	1.09	0.10
Intermediate Consumption	5602	7004	6362	392
Depreciation	3955	4815	4436	226
HORTICULTURE				
Output	41461	70735	57969	9282
UAA	2.44	3.39	2.87	0.28
Labour (AWU)	1.84	2.42	2.09	0.18
Intermediate Consumption	8400	16888	12426	2285
Depreciation	4696	7314	6003	664
VINEYARDS				
Output	15924	34832	24110	6125
UAA	4.04	6.05	4.59	0.69
Labour (AWU)	0.84	1.33	1.12	0.17
Intermediate Consumption	2300	4459	3626	643
Depreciation	2926	4655	3816	534
FRUITS				
Output	20583	27659	24102	2147
UAA	5	5.55	5.21	0.18
Labour (AWU)	0.96	1.25	1.11	0.09
Intermediate Consumption	3028	4097	3535	341
Depreciation	3319	4605	3892	412
OLIVES				
Output	7769	20884	13228	2908
UAA	5	5.55	5.23	0.17
Labour (AWU)	0.77	1.18	0.99	0.16
Intermediate Consumption	1119	1734	1435	190
Depreciation	2150	2928	2481	260
PERMANENT CROPS				
Output	13916	22452	17873	2457
UAA	4.77	6.34	5.28	0.54
Labour (AWU)	0.85	1.31	1.10	0.18
Intermediate Consumption	1843	2338	2016	156
Depreciation	2559	4260	3192	576
MIXED CROPS				
Output	22638	29035	25909	2298
UAA	7.22	10.45	9.04	1.04
Labour (AWU)	1.11	1.49	1.35	0.12
Intermediate Consumption	3315	5030	4151	613
Depreciation	2846	4399	3641	559

- Intermediate consumption in Euros as the sum of SE285 (seeds and plants), SE295 (fertilizers), SE300 (crop protection) and SE305 (other crop specific costs)
- Capital depreciation in Euros (SE360)

Similar variables have been used by Petrick and Kloss (2012), Błażejczyk-Majka and Kala (2015) and Petrick and Kloss (2018). The output expressed in Euros was deflated by the price indices for crop production whereas the inputs with the purchase prices of the means of agricultural production. The descriptive statistics of the sample are reported on Table1. During 2004-2017 horticulture farms was on average the biggest farms in terms of both output produced and inputs used. In addition they have the lowest area of all samples. COP and field crops farms have the highest land use.

5. Results

The empirical results are presented similarly to O'Donnell (2012b). Table 2 reports Färe-Primont estimates of TFP and TFPE changes in crop production between 2004 and 2017. These estimates are obtained under the assumption that in any given period all crops experience a same set of production possibilities. This means that all crops face the same estimated technical change in each period which can be observed in the first and second column of TFP^* estimates in Table 2. The third column of TFP^* reveals that over the examined period, on average, each crop in Greece experiences around 11% technical regress. In 2004 all crops were more productive than COP apart from olives which were 12% less productive. In both years horticulture is the most productive farming. The largest decrease in TFP occurred in field crops (19%) while the largest increase (19%) occurred in olives farms followed by COP (18%) and permanent crops (4%). The last row of the Table shows average estimates for the total crop farming in Greece. It shows that, on average, Greek crop production experienced a 3% productivity decrease between the periods 2004 and 2017. The large decrease (11%) in TFP^* shows the technical regress which appears during the study period. The changes of TFPE suggest that horticulture, fruits, and mixed crops maintained their overall efficiency in both years while COP, olives and permanent crops improved their efficiency. However, in field crops and vineyards efficiency is deteriorated. Three (COP, olives, permanent crops) out of eight farms have experience productivity improvement due to their improvement in overall efficiency i.e., technical regression is being fully offsetted by the efficiency improvement which causing an improvement in productivity. For example, 19% productivity improvement of COP is a combined effect of 11% technical regress and 32% efficiency improvement. However in field crops both technical regress and efficiency falls are acting together and resulting in about 20% decrease in their productivity. On the other hand, horticulture, vineyards and fruits experience falls in their productivity (11%, 13% and 9%) due to the technical regress. On average, the main driver of the 3% decrease in Greek crop production productivity is the technical regress (11%) which prevails the improvement in overall efficiency by 6%.

The next step of the analysis is to determine the main component of the overall efficiency (TFPE) that contributes to the inefficiency of each farm. Therefore, Table 3 presents the decomposition of TFPE into OTE and OSME according to equation (10). All farms have almost OTE equal to 1.00 in 2004 which means that pure technical efficiency is achieved. This implies that any change in TFPE is due solely to changes in OSME. These technical efficient farms apart from vineyards and field crops have improved their overall efficiency due to the increase in OSME which means that farms have adjust their scale and scope of production more than optimally. Horticulture is the most efficient and most productive farming. In 2017, field crops and mixed crops became technically inefficient (OTE<1) where they produce less output than the maximum output could be obtained given the set of inputs used. In the case of field crops both OTE and OSME contribute to the 10% decrease in TFPE, where mixed crops have maintained their overall efficiency because the the 6% decrease in pure technical efficiency has been totally offset by the increase (7%) in scale and mix efficiency.

Table 2.TFP Change, Technical Change and Efficiency Change: 2004-2017

	TFP			TFP^*			$TFPE=TFP/TFP^*$		
	2004	2017	Δ[1]	2004	2017	Δ	2004	2017	Δ
COP	1.00	1.18	1.18	1.00	0.89	0.89	1.00	1.32	1.32
Field crops	1.41	1.14	0.81	1.00	0.89	0.89	1.41	1.27	0.90
Horticulture	1.97	1.76	0.89	1.00	0.89	0.89	1.97	1.97	1.00
Vineyards	1.43	1.25	0.87	1.00	0.89	0.89	1.43	1.40	0.98
Fruits	1.34	1.22	0.91	1.00	0.89	0.89	1.34	1.36	1.01
Olives	0.88	1.05	1.19	1.00	0.89	0.89	0.88	1.18	1.34
Permanent crops	1.12	1.17	1.04	1.00	0.89	0.89	1.12	1.31	1.17
Mixed crops	1.33	1.19	0.89	1.00	0.89	0.89	1.33	1.33	1.00
CROP OUTPUT	1.27	1.23	0.97	1.00	0.89	0.89	0.67	0.71	1.06

Note:[1]$\Delta TFP=TFP_{t+1}/TFP_t$

Connecting the results of Table 2 and Table 3, we conclude that farms (COP, olives and permanent crops) experience increase in TFP due to the improvement of scale and mix efficiency. However, farms (field crops and vineyards) the decline in TFP is due to technical regress and in the fall of both pure technical efficiency and scale and mix efficiency. Besides, in farms (horticulture, fruits and mixed crops) with also a decline in TFP is mainly due to technical regress.

Table 3.Output-Oriented Components of Efficiency Change

	TFPE=OTE×OSME			OTE			OSME		
	2004	2017	Δ	2004	2017	Δ	2004	2017	Δ
COP	1.00	1.32	1.32	1.00	1.00	1.00	1.00	1.32	1.32
Field crops	1.41	1.27	0.90	1.00	0.96	0.96	1.41	1.32	0.94
Horticulture	1.97	1.97	1.00	1.00	1.00	1.00	1.97	1.97	1.00
Vineyards	1.43	1.40	0.98	0.99	1.00	1.01	1.44	1.40	0.97
Fruits	1.34	1.36	1.01	1.00	1.00	1.00	1.34	1.36	1.01
Olives	0.88	1.18	1.34	1.00	1.00	1.00	0.88	1.18	1.34
Permanent crops	1.12	1.31	1.17	1.00	1.00	1.00	1.12	1.31	1.17
Mixed crops	1.33	1.33	1.00	1.00	0.94	0.94	1.33	1.42	1.07

Table 4 reports estimated annual rates of growth in TFP, maximum TFP (TFP^*) and TFPE per farming in three sub-periods 2004-2008, 2008-2014 and 2014-2017. The year 2008 has been chosen as the beginning of the economic crisis in Greece and 2014 as the year where the TFP for all crops has increased compared with COP in 2004. Before crisis (2004-2008) COP faces the largest average growth rate of TFP growth. During this sub-period crop production experiences a 0.13% annual average rate of technical progress. Additionally, field crops have the largest drop in TFP at an annual average rate of almost -6% due to the deterioration in overall efficiency at an annual average rate at almost -6%. The TFP growth has been negative for permanent crops (-3%) due to the decline in TFPE by -3% annual average rate. Six years after crisis (2008-2013) all crops apart from field crops experience negative growth rates of TFP due to the technical regress. In this sub-period technical change dropped as low as -4.79% implying technical regress. In the case of field crops the technical regress offset by the 7% increase in TFPE. However, the contrary happens for COP, fruits and permanents crops. In the more recent period 2013 to 2017 the TFP growth has been negative only for field crops and fruits due to the TFPE deterioration. This sub-period is characterized by technical progress which is the main driver of the positive TFP growth. Olives have the highest average growth rate in TFPE contributing together with the technical progress to the high positive average growth rate of TFP (13.12%). Finally, for the whole period TFP growth has been negative (-0.25%) as resulted by the negative TFP growth during the first two sub-periods. The five years after crisis influence the growth of TFP and its components during the examined period.

Table 4. Average Annual Rates of Growth in TFP index and Efficiency (%)*

	2004-2008			2008-2013			2013-2017			2004-2017		
	TFP	TFP*	TFPE	TFP	TFP*	TFPE	TFP	TFP*	TFPE	TFP	TFP*	TFPE
COP	5.54	0.13	5.41	-2.13	-4.79	2.67	1.25	3.05	-1.79	1.18	-0.81	1.98
Field crops	-5.76	0.13	-5.88	1.98	-4.79	6.77	-2.13	3.05	-5.18	-1.55	-0.81	-0.74
Horticulture	0.13	0.13	0.00	-4.79	-4.79	0.00	3.04	3.05	0.00	-0.81	-0.81	0.00
Vineyards	0.45	0.13	-0.58	-4.74	-4.79	0.06	3.07	3.05	0.03	-0.94	-0.81	-0.14
Fruits	1.94	0.13	1.81	-2.91	-4.79	1.89	-0.63	3.05	-3.68	-0.66	-0.81	0.14
Olives	-0.78	0.13	-0.91	-6.36	-4.79	-1.56	13.12	3.05	10.08	1.25	-0.81	2.06
Permanent crops	-3.04	0.13	-3.16	-1.24	-4.79	3.55	5.72	3.05	2.67	0.32	-0.81	1.13
Mixed crops	-0.82	0.13	-0.95	-4.17	-4.79	0.63	3.20	3.05	0.15	-0.81	-0.81	0.00
CROP OUTPUT	-0.29	0.13	-0.53	-3.05	-4.79	1.75	3.33	3.05	0.29	-0.25	-0.81	0.54

Note: *The average annual rate of growth in a variable *Z* between periods *t* and *s* is calculated as $\Delta \ln Z = \ln(Z_t / Z_s)/(t-s)$. For example the average annual rate of growth of TFP in the 2004-2008 is $\Delta \ln TFP = \ln(TFP_{2008}/TFP_{2004})/(2008-2004)$.

In Table 5 the evolution during 2004-2017 of the Färe-Primont productivity index is presented where it compares the TFP of each crop with the TFP of COP in 2004. It is clear that in 2017 all crops have improved their productivity compared with COP in 2004. The most decreases occurred in olives and permanent crops where increases happened in the rest of the crops. The largest increases were noticed in horticulture in relation with COP.

The annual evolution of the TFP index is presented graphically in Figure 1. The diagram shows the declining trend of TFP index. Over the study period, horticulture leads other crops since it maintains the maximum TFP among crops (TFP =TFP*).

Table 5. Indexes of Changes in Total Factor Productivity in Crop Production (base COP 2004=1)

	COP	Field crops	Horticulture	Vineyards	Fruits	Olives	Permanent crops	Mixed crops
2004	1.000	1.409	1.967	1.429	1.336	0.883	1.116	1.335
2005	0.972	1.471	2.081	1.689	1.426	1.235	1.276	1.375
2006	0.972	0.984	2.119	1.626	1.339	0.908	1.019	1.362
2007	1.243	1.098	1.911	1.372	1.400	0.858	0.940	1.329
2008	1.248	1.120	1.977	1.404	1.444	0.856	0.989	1.292
2009	1.066	1.149	1.879	1.274	1.341	0.749	0.894	1.281
2010	0.981	1.072	1.685	1.113	1.283	0.730	0.903	1.223
2011	1.265	1.237	1.508	1.166	1.148	0.764	0.784	1.007
2012	1.279	1.186	1.522	1.131	1.278	0.887	0.943	1.068
2013	1.122	1.236	1.555	1.108	1.249	0.623	0.929	1.049
2014	1.246	1.295	1.963	1.088	1.235	1.070	1.234	1.147
2015	1.076	1.050	1.796	1.039	1.108	0.821	0.964	1.041
2016	1.192	1.166	1.678	1.000	1.153	0.815	0.910	1.070
2017	1.180	1.135	1.757	1.252	1.217	1.052	1.168	1.192

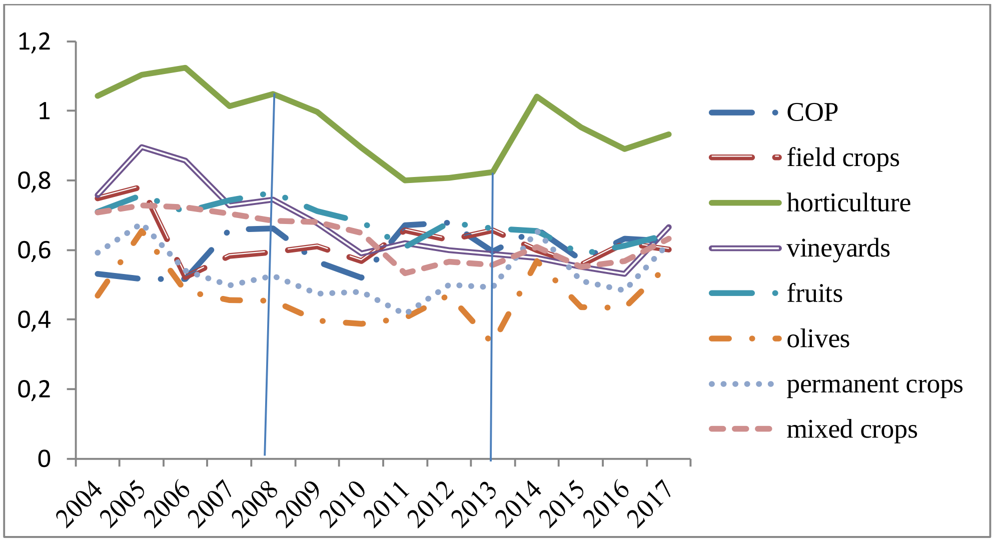

Figure 1. Productivity Levels in Different Crops: 2004-2017

6. Conclusions and Policy Implications

This article, for the first time, estimates TFP index in eight different crop farms of the Greek agricultural sector for each year between 2004 and 2017 using Färe Primont index which belongs to the family of multiplicative-complete economically ideal productivity indexes. The empirical results show that in 2017 only three out of eight farms have exhibited an increase in TFP index in relation to 2004. The most productive farm in 2017 is horticulture and the least productive olive farms. Beside, most of the crops are fully technical efficient. COP and olives farming face a similar increase in TFP (18% and 19%), followed by permanent crops (4%).The highest decrease in TFP occurred in field crops farms by 19% while the lowest decrease happened to fruits farms (9%). It is found the examined period is characterized by technical regress (an average rate of -0.81% per annum).

Regarding their overall efficiency (TFPE) three out of eight farms have improved their efficiency, three farms have maintained their efficiency and two farms have deteriorate their efficiency. In the COP, olives and permanent crops the gain in efficiency has offsetted the impact of technical regress resulting in the improvement of their TFP. Specifically, these farms are technical fully efficient producing on the production frontier and the improvement of scale and mix efficiency over the entire period is indeed the main source in the increased efficiency of the farms. In the case of mixed crops farms any gains in their scale and mix efficiency were lost in favor of the negative technical change and technical inefficiency.

The main findings of our study can be summarized as follows. Firstly, the sub-period 2008-2013 (the first five years of the crisis) is mainly responsible for the negative growth of total factor productivity which is characterized by high technical regression (average rate -4.79% per annum). Secondly, the increase in TFP for COP, olives and permanent crops farms is mainly due to scale and mix efficiency increase by 32%, 34% and 17% respectively. Finally, the driver of the deterioration of TFP in horticulture, vineyards, fruits and mixed crops is technical regress.

The result of technical regress, which appears to be the main factor for the downturn in total factor productivity, can drive us to address some important policy implications. There is a need for technology improvement which requires the public sector to play an active role in increasing investments in public research and development with emphasis on the applications of results to farming. As O'Donnell (2011a) argues research and development policies have a great effect on technological change.

The government should exploit the EU's long-term strategy for agricultural research and innovation launched by the *European Innovation Partnership* to support the creation of operational groups in crop farming.

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