A QUANTITATIVE ANALYSIS OF AGRICULTURAL PRODUCTION IN GREECE, 2004-2016

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Abstract

The paper looks into agricultural production at the subnational level in Greece, across four regions (Thessaly, north Greece, west Greece, the rest of Greece) from the EU's 2003-04 CAP reform and 2004 enlargement by ten member-states to the end of the country's long economic recession in 2016. It relies on annual observations running from 2004 to 2016, supplied by the EU Commission, and plots the evolution of output, of labor, of capital, of the land-area used, of energy costs, of the respective average productivities, and of the output to energy costs ratio. In addition, it econometrically estimates the impact of the said inputs on output, and the magnitude of multifactor productivity (i.e., of entrepreneurship, technology and of the impact of the factors not considered in the regression) in a translog production function framework. Alternative specifications are considered and all regressors are rendered uncorrelated to each other so as to deal with heteroscedasticity. The results suggest that labor and the cost of energy are the main explanatory factors. However, their impact along with the size of multifactor productivity vary across space. This implies that there is room for spatially differentiated interventions.

Keywords: Cobb-Douglas, translog, agricultural production, productivity, regional analysis, Greece

1. Introduction

The purpose of the paper is to study the economics of production in the agricultural sector in Greece across regions −north Greece, west Greece, Thessaly, the rest of Greece− from 2004 to 2016. That is, from the time of the EU's largest expansion and CAP reform to the end of the country's 2009-16 economic recession.[1] According to Eurostat figures, during these thirteen years both the gross value added at constant prices and labor in terms of work units in Greece decreased by approximately 19 and 32%, respectively. Among the EU's fifteen older member states the former increased by approximately 1% and the latter decreased by 19%; while among the EU's ten newer member states the former increased by approximately 4%, and the latter decreased by 23%.[2]

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[1] The collective agricultural value of the ten new member-states was 2-3 times that of Greece. The CAP reform of 2003-05 decoupled direct payments to farmers from production. The CAP reform of 2013-14 aimed to strengthen the competitiveness of the sector, promote sustainable farming and innovation, support jobs and growth in rural areas and move financial assistance towards the productive use of land.

[2] The figures were accessed via https://ec.europa.eu/eurostat/data/database > 'Agriculture, forestry and fisheries' > 'Agriculture' > 'Economic accounts for agriculture' and 'Agriculture input statistics', last updated, respectively, in March and February of 2020.

Consequently, sectoral figures in Greece seem to have deviated considerably from the general direction of the other EU members at the time, and from the previous pattern of relative of slow gradual increase or stability (Prodromídis, 2000). Interestingly, the agricultural sector has been seen as a fallback during Greece's economic recession (e.g., Giannakis and Bruggeman, 2017.) To probe what transpired the paper uses the annual input and output data associated with the average farm in each of Greece's four territorial divisions, as provided by the European Commission's Farm Accountancy Data Network (FADN).[3]

Similar agricultural production issues have been studied, and analyses been carried out in a number of countries in recent years (e.g., Ghate et al. 2016; Nowak and Kijek, 2016; Zwolak, 2017; Adom et al. 2018; European Commission, 2018; Güvercin, 2018; Jiménez et al., 2018; Ogunlesi et al., 2018; Castro et al., 2019; Giang et al., 2019; Roy, 2019; and others) on the basis of aggregated data; and many more have focused on individual subsectors, products, regions or subregions. This is also the case in Greece. Quantitative analyses of the sector's aggregate output on the basis of inputs are few and far between. One prepared by Nastis et al. (2012) was performed at the national level, in a Cobb-Douglas econometric framework, and covered a seventeen-year period: from 1980 to 2007.

The rest of the paper is organized as follows: Section 2 describes the data. Section 3 discusses modeling issues for the econometric estimation of the sector's production function. Section 4 supplies the empirical findings; and Section 5 provides the conclusions.

2. Data description

In theory, the level of production (output), Q, depends on the quantity and quality of inputs, the way inputs are combined, and the factors shaping people's demand. The inputs consist of labor (specialized and/or unskilled), L; manmade capital (the stock of buildings, K1, and machines, K2), K; the land (earth's surface in the broad sense: area size and configuration, water, flora-fauna-minerals etc.) in terms either of value, Ta, or size (hectares) Tb; energy, E, in monetary figures; and various other materials used in the process (all obtained from land, labor and capital), M.

The descriptive statistics of the FADN data are provided in Table 1, and suggest that during the time in question, on average, holdings in: (i) The north part of the country (running from West Macedonia to West Thrace, along with the islands of Thasos and Samothraki) featured more K_2 and T_b, a higher value of livestock, and higher costs for E, feeds, seeds, fertilizers, and such inputs. (ii) The west part of the country (spanning Epiros, the Ionian islands and the Peloponnese) were associated with higher T_a. (iii) Thessaly (in central Greece) and north Greece provided more Q. (iv) The rest of Greece (i.e., the part of the mainland situated south of Epiros and Thessaly, and north of the Peloponnese, plus Crete and the other Aegean islands) relied on more L, used more K_1, livestock (in terms of heads), and carried out more investments in buildings and machinery.

[3] The sample is quite reasonable, involving, for instance, 4,253 (4,254) farms representing 390,320 (347,339) farms in 2004 (2014).

Table 1. *Descriptive statistics of agricultural production in Greece, 2004-16 (average holding, annual data)*

Variables		north country [i]		west country [ii]		Thessaly [iii]		Rest of Greece	
		mean	std.dev	mean	std.dev	mean	std.dev	mean	std.dev
1.	Output (Q) in €	23904	1864	20731	1627	23949	1785	22201	1403
2.	Labor (L) in full-time person equivalent (FTPE)	1.13	0.09	1.16	0.19	1.18	0.12	1.35	0.10
3.	Terrain (T)								
	a. Value in € (T_a)	51672	9370	77158	19999	68001	5196	73184	9601
	b. Utilized area in hectares (T_b)	11.31	0.85	6.34	1.00	10.48	0.97	7.85	1.80
	c. Value per hectare: (a)/(b)	4547	690.0	12036	1610.9	6535	682	9551	1217
4.	Capital, investment, costs in €								
	a. Stock of buildings (K_1)	8086	1104	7467	3522	5474	1071	8734	1654
	b. Stock of machinery (K_2)	24868	6300	12690	4810	20189	5840	13519	3404
	c. New buildings-machinery (I)	677	175	526	120	607	380	942	191
	d. Costs for feeds, seeds etc. (M)	8251	935	5011	874	7470	755	6014	470
	e. Breeding livestock converted in head units	6.10	0.56	5.30	0.52	6.37	0.64	7.16	0.35
	f. Breeding livestock in €	4683	6459	2894	216	4161	63	4171	174
	g. Cost of energy (E) in €	2371	609	1091	332	2363	559	1489	348

Notes: [i] The north country consists of Western, Central and Eastern Macedonia, Western Thrace, the islands of Thasos and Samothraki.
[ii] The west country consists of Epirus, the Ionian islands, the Peloponnese (excluding Troezin), and the western Genranian mountains area.
[iii] Thessaly is taken to include the (northern or Thessalian) Sporades islands.

Source: EU FADN; own calculations based on the annual data.

In addition, Figure 1, regarding the evolution of output and of the main inputs involved, and Figure 2, featuring ratios of the two, reveal that:

a. *Q* generally increased over time; was higher in north Greece and Thessaly, and lower in west Greece and the rest of Greece. (In the latter two regions it evolved very much the same from 2008 onwards.)

b. *L* generally decreased over time; was lower in Thessaly during 2004-2006, in north Greece during 2007-2010, in west Greece during 2011-6, and higher in the rest of Greece.

c. *K* increased over time, much in the same manner across all regions, and was higher in north Greece, modest in Thessaly, and lower in west Greece during 2004-10, and in both west Greece and the rest of Greece during 2011-16.[4] Given *L*'s decrease and *K*'s increase, obviously the sector moved from a more labor-intensive (less capital-intensive) to a less labor-intensive (more capital-intensive) state.

d. T_b generally increased over time; was lower in west Greece throughout the period, and in the rest of Greece during 2004-08; and higher in north Greece, Thessaly, and (at the end of the period) in the rest of Greece.

e. The cost of *E* generally increased over time; was higher in north Greece and Thessaly, lower in west Greece, and modest in the rest of Greece.

f. Labor productivity (*Q/L*) increased over time; was higher in north Greece, in Thessaly during 2004-6 and 2012-16, and in west Greece during 2012-16, modest in Thessaly during 2007-

[4] It seems that in 2010-11, the government attempted to direct to the primary sector an exceptional amount of EU-funding (Giouroukeli, 2010). The 75% increase observed between 2010 and 2011 in western Greece corresponds to the largest change observed across all inputs.

11, and in west Greece during 2010-11, and lower in west Greece during 2004-10, and in the rest of Greece.

g. Capital productivity (*Q/K*) decreased over time; was lower in north Greece, and higher in west Greece up to 2010, and subsequently in Thessaly and the rest of Greece.

h. Land productivity (Q/T_b) generally decreased over time; was higher in west Greece from 2008 on, and the rest of Greece during 2004-8, modest in the rest of Greece during 2009-12, and lower in north Greece and Thessaly throughout the period, and in the rest of Greece during 2013-6.

i. The proxy for energy productivity (*Q/E cost*) decreased over time; was higher in west Greece, lower in Thessaly and north Greece (it evolved very much the same), and modest in the rest of Greece.

Figure 1. *Agricultural inputs and output in Greece, 2004-16 (average holding, annual data*)

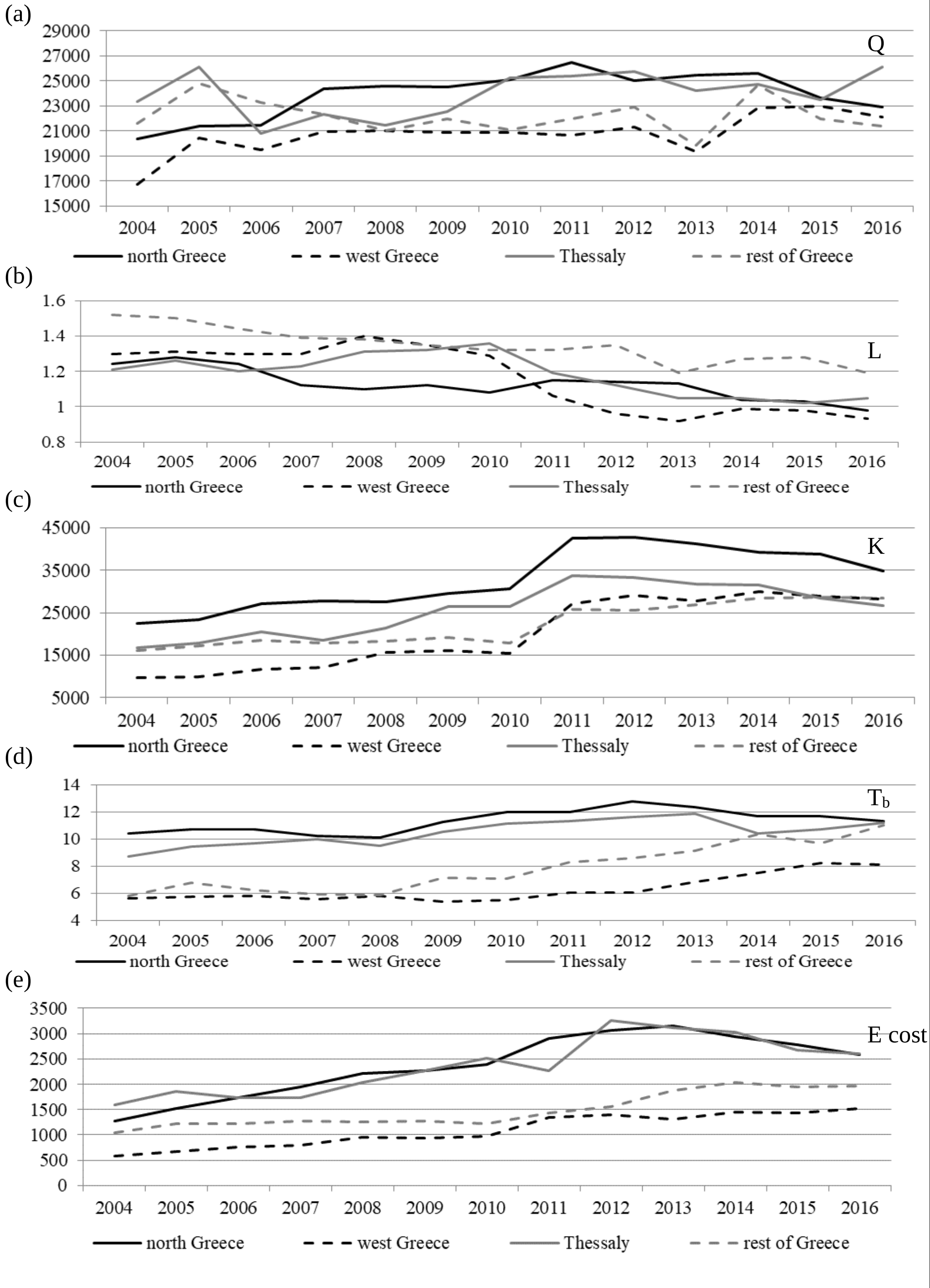
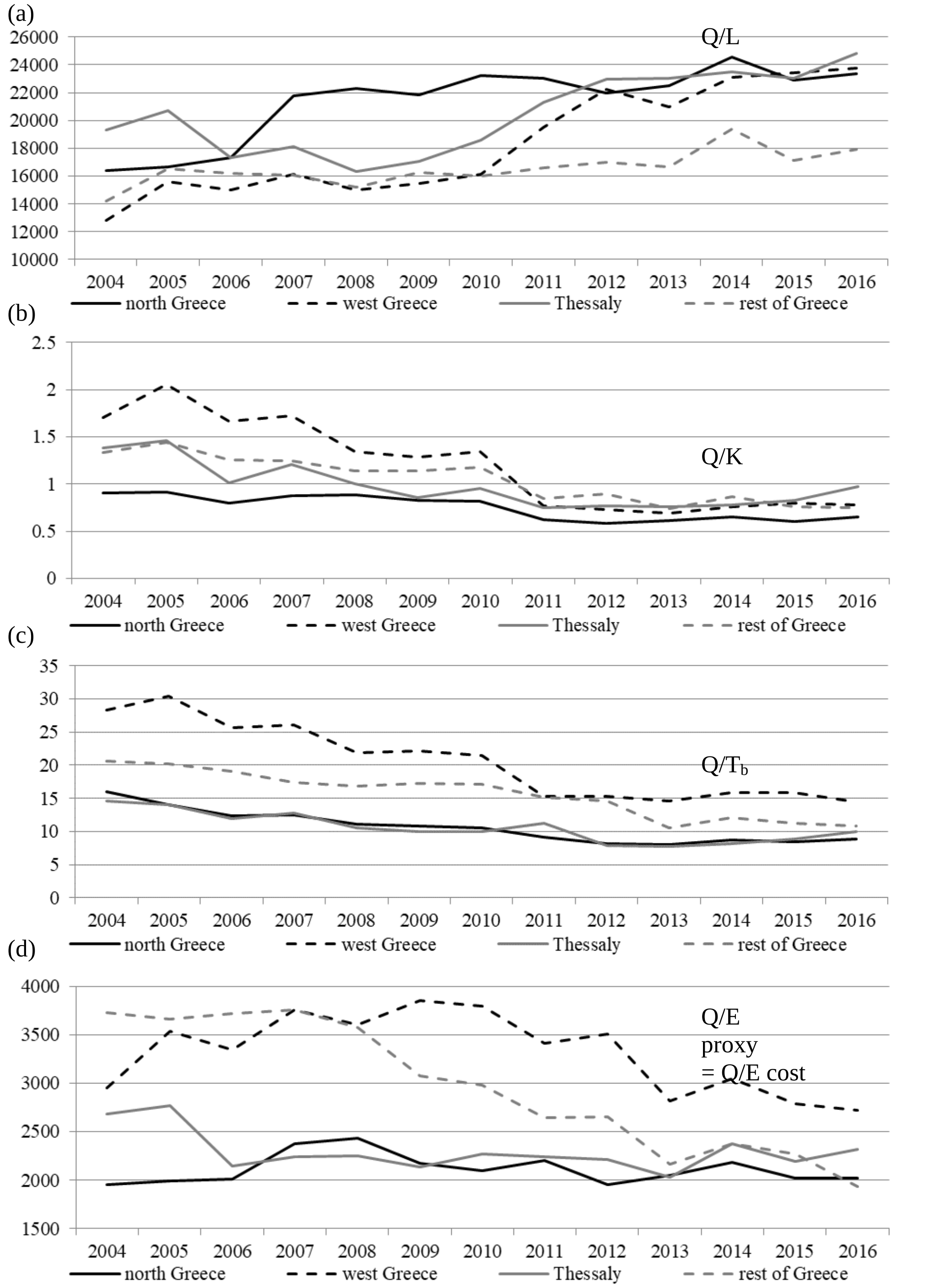


Figure 2. *Productivity in agricultural across Greece, 2004-16 (average holding, annual data*)



3. Modeling issues

To properly look into and, especially, isolate the impact of these inputs on production we turn to econometrics. First, we select a model that rules out both production on the basis of a single input and any requirement the input effects (coefficients or parameters) add up to a certain number. The simplest approach is to employ a transcendental logarithmic (or translog) production function with a linear or non-linear time-trend (Tzouvelekas, 2000). It very much recalls the Cobb Douglas (CD) production function −the most ubiquitous production function in theoretical and empirical analyses (Charnes et al., 1976; Felipe and Adams, 2005; Biddle, 2011)− though it is much more flexible than the CD or the extended CD expression. (Alternatively, the CD function and its variants are *nested* translog functions.)

Given the available inputs, the extended CD production function is of the form:

$$Q = A\ L^a K^b T^c E^d M^g u, \tag{1}$$

with u denoting the error term; the other lower case letters standing for input coefficients; the five upper case letters, from L to M, standing for the inputs; and A standing for multifactor productivity (MFP), i.e., the element that captures (a) the impact of entrepreneurship and technology (E&T) in combining the inputs involved, as well as (b) the impact of other factors not specified in the expression (e.g., Chiang, 1984; Duffy and Papageorgiou, 2000; Erken et al., 2016).

In this context, the dependent variable, Q, is determined by the five independent variables, namely, L, K, T, E, M; and the unknown terms (A, and the exponents) are estimated econometrically, simultaneously, on the basis of the known values of the dependent and independent variables. The exponents of L and K and of the other inputs are used to calculate the *marginal productivities* of the respective inputs, for instance, the marginal productivity of labor, aQ/L, and the marginal productivity of capital, bQ/K. In addition, if the sum of the exponents equals one, then the production function exhibits constant *returns to scale*. This means that doubling the use of the inputs will double output. Conversely, if the sum of the exponents exceeds (is below) one, then the production function exhibits increasing (decreasing) returns to scale. This means that doubling the use of the inputs will more than double (less than double) output.

As the data are cross-sectional and longitudinal, each of the four regions and each of the thirteen years are indicated with i (=1, …, 4), and t (=1, …, 13), respectively:

$$Q_{it} = A_{it}\ L_{it}^a K_{it}^b T_{it}^c E_{it}^d M_{it}^g u_{it}. \tag{2}$$

Following the example of J. Tinbergen (Nobel Prize laureate of 1969), to allow A_{it} to vary over time (Wallis, 1973), A_{it} is specified as $A_{it} e^{\lambda it}$, with λ representing the trend's slope:

$$Q_{it} = A_{it}\, e^{\lambda it}\ L_{it}^a K_{it}^b T_{it}^c E_{it}^d M_{it}^g u_{it}. \tag{3}$$

Equivalently:

$$lnQ_{it} = lnA_{it} + \lambda_i t + a\ lnL_{it} + b\ lnK_{it} + c\ lnT_{it} + d\ lnE_{it} + g\ lnM_{it} + u_{it}. \tag{4}$$

In addition, in order to capture input-interaction effects and each input's rate of change, additional terms in multiplicative and squared value form are considered (e.g., Lyu, 1984).

In the case of incorporating the squared value of certain inputs, the expression takes the following form when the coefficients turn out to be statistically significant at the 5% level:

$$lnQ_{it} = $$

$$lnA_{it} + \lambda_i t + a\ lnL_{it} + h(lnL_{it})^2 + b\ lnK_{it} + k(lnK_{it})^2 + c\ lnT_{it} + d\ lnE_{it} + m(lnE_{it})^2 + g\ lnM_{it} + u_{it}. \tag{5}$$

In recent years, Kea and Pich (2016), Mohamed et al. (2016), Yang et al. (2016), Lachaud (2017), Schettini and Azzoni (2018), Wree (2018), Bai et al. (2019), Cai and Yan (2019), Gong et al. (2019), Njuki and Bravo-Ureta (2019), and others, analyzed agricultural production in the same manner. In the case considered hereinafter, the recovery of low p-values for the coefficients of the aforesaid squared values and of the trend, suggests that the expression is more appropriate compared to its extended CD counterpart. However, the employment of a full-blown translog formula with additional product terms is tempered by the practical need to conserve degrees of freedom (DoF).

Another issue to address is stationarity (or non-stationarity). That is, if the mean and variance of the variables involved do not vary (or vary) over time.[5] To deal with non-stationarity one may (Maddala, 2001; Gujarati, 1995):

(a) Incorporate in the analysis ‒in the right-hand side of expression (2) to be exact‒ a trend term, *t*. As already mentioned, the term is part of expression (4). (See Model A, hereinafter.)

(b) Detrend the variables involved. (See Model B.)

(c) Rely on successive differences. (See Models C-D.)

All three are technically simple, though, in order to preserve DoF, we will not proceed beyond first differences in the case of (c).[6]

Last but not least, all explanatory variables are made linearly independent of one another. In case the terms are ordered as above: (a) *lnL* is made linearly independent from *t*; (b) *lnK* is made linearly independent from *t* and *lnL*; (c) *lnT* is made linearly independent from *t*, *lnL* and *lnK*; (d) *lnE* is made linearly independent from *t*, *lnL*, *lnK*, and *lnT*; *lnM* is made linearly independent from all the rest; thus, satisfying a basic assumption regarding the independence of regressors (e.g., by Economou et. al., 2019, and the literature cited therein). In essence, instead of regressing *lnQ* on arguments *t*, lnL_{it}, lnK_{it}, lnT_{it}, lnE_{it}, and lnM_{it}, initially lnL_{it} is regressed on *t*, an lnL_{it}' is predicted, and an orthogonal $lnL_{it}^{\circ} = lnL_{it} - lnL_{it}'$ is estimated; next, lnK_{it} is regressed on *t* and lnL_{it}°, an lnK_{it}' is predicted, and an orthogonal $lnK_{it}^{\circ} = lnK_{it} - lnK_{it}'$ is estimated, and so on. Thus, we may explain *lnQ* in terms of *t*, lnL_{it}°, lnK_{it}°, and additional regressors estimated in the same manner. Consequently, in the context of Tables 2-5, the second regressor is independent of the first regressor, the third regressor is independent of the former two, and so on. Indeed, since in the first column of Table 3 the second regressor (lines 6-9) is *t*, all other explanatory variables (regarding the inputs used) are made linearly independent of *t*. Obviously, the order of the regressors employed affects the size of the estimated parameter (coefficient) for if the order was different, a different number of effects would be subtracted from each explanatory variable. In the analyses that follow labor is ordered prior to other inputs, and all orders of other inputs are considered in each model. We provide the specifications associated with the highest levels of fitness.

4. Empirical results

The analysis is carried out in Stata. As already mentioned, alternate models are considered:

- Model A is based on expression (5).
- Model B is a variant of expression (5) without a trend (for it employs detrended variables.)[7]
- Model C is based on the first differences of expression (2).[8]
- Model D is a linear arrangement of the first differences of the terms involved in expression (2). It is undertaken in order to provide a sense of how things might look like in a perfect input substitution setting,[9] outside the extended CD or translog framework.

Each model is estimated in both panel and pooled format. In the case of the former, the random effects (RE) variant is always preferred over its fixed effects (FE) counterpart on the basis of the

[5] This is important as certain analytical tools and models employed in a number of studies –not in this one– rely on the mean and variance being fixed. Short time series are not typically tested for non-stationarity, though for $t \geq 10$ testing is possible (e.g., by Hlouskova and Wagner, 2006).

[6] The findings of the relevant stationarity tests are supplied in the notes of Tables 2-5.

[7] These are variables regressed on *t*, on the basis of which the trend element is subtracted.

[8] The product terms of expression (5) turn out to be statistically insignificant in the preliminary analysis and are abandoned.

[9] Recent examples of such agricultural production models are provided by Wouterse (2017), Ogbuabor and Nwosu (2017), Osabohien (2018).

Hausman (1978) test;[10] and in the case of the latter, spatial dummies are employed so that individual regional effects (if any) may be spotted. To deal with heteroscedasticity, all analyses are carried out with robust standard errors. (Huber, 1967; White, 1984). The best fits of the both the RE and the pooled analysis results are presented in Tables 2 and 3, respectively. By and large, they rely on *L*, *E*, and either *M* or *T* or *K* or its variants (K_1 or investment, *I*).

From the RE results associated with low p-values (less than 1%), the coefficients regarding *L* (in Models B-D), T_a , the cost of *E* (Models B and D), and the cost of feeds, seeds, fertilizers etc. (in Model A) are associated with a positive sign; while the coefficient regarding K_1 (in Model C) is perhaps associated with a negative sign (the p-value = 0,011). This suggests that, *ceteris paribus*, to increase *Q* it might be better if K_1 were reduced.

Table 2. *Random effects GLS regressions with robust standard errors on holding output across Greece, 2004-16*

	Explanatory variables	Model A log-log	Model B log-log detrended	Model C log-log first differences	Model D linearly arra-nged first differences
1	Constant	10.056	9.808	0.014	299.261
2	Labor in FTPE (L)	-0.169	0.362	0.963	17,023.100
3	Labor in FTPE, squared			4.737	66,297.340
4	Costs for feeds, seeds etc. (M)	0.316			
5	Value of land (T_a)		0.382	0.227	0.079
6	Stock of buildings (K_1)			-0.163	
7	Cost of energy	0.124	0.175		1.699
	St. Dev. (u)	0	0	0	0
	St. Dev. (e)	0.060	0.049	0.074	1667.042
	Rho (fraction of variance due to u)	0	0	0	0
	Observations (N)	52	52	48	48
	Number of groups	4	4	4	4
	Model fitness (R^2)				
	• within	41%	25%	34%	33%
	• between	100%	99%	31%	90%
	• overall	64%	81%	34%	33%

Notes: The second regressor is linearly independent of the first regressor, the third regressor is linearly independent of the former two regressors, and so on. Opinions regarding the need for stationarity testing in this kind of short sample vary. When the Levin et al. (2002) test is considered the depended variables (the depended variable and two other variables) in Models C-D (Model A) turn out as non-stationary and the other variables of all Models turn out as stationary. When the Breitung (2001) and Hadri (2000) tests are considered all variables in Model A turn out as non-stationary and all variables of the other Models turn out as stationary. When the Harris and Tzavalis (1999), Im et al. (2003) test are considered one and two regressors, respectively, turn out as non-stationary in Model A, and all variables in the other Models turn out as stationary.

P-values over 0.000: Model A: (2nd line) 0.011, (7th line) 0.032. Model C: (6th line) 0.011, (5th line) 0.024, (1st line) 0.044. Model D: (5th line) 0.004, (2nd line) 0.005, (1st line) 0.020, (3rd line) 0.059. The rest are equal to 0.000.

Source: As in Table 1.

[10] The respective p-values of the null hypotheses are 0.6138, 0.1778, 0.9830, 0.9891.

Model B exhibits the highest level of fitness; Model A exhibits a modest level of fitness, is also less likely to satisfy stationarity proponents; and both conform to the extended CD format. Model C has a typical CD component and an added component (in particular: $Q = 1.014\ L^{0.963}\ T^{0.227}\ K_1^{-0.163}\ e^{4.737(\ln L)(\ln L)}$). Overall, the estimated coefficients of Models A and B add up to less than one, while the estimated coefficients of Model C to more than one. This suggests decreasing returns to scale (DRTS) and increasing returns to scale (IRTS), respectively. Model D is based on a linear arrangement of terms (of the sort $dQ = a\ dL + c\ dT + d\ dE + u$). This implies that the production function is linear and, hence, is irreconcilable with the multiplicative CD setting of expression (1). Indeed, it suggests that inputs are perfect substitutes and, hence, allows for production entirely without L (and/or other inputs). As it is associated with the lowest R^2, it turns out to be the weakest not only on theoretical grounds but also in terms of empirical fitness.

The pooled analysis (Table 3) provides more information at the regional level. The results associated with low p-values (less than 1%) reveal:

- Considerable E&T heterogeneity across space and time: The term associated with A_{it} is higher in Thessaly (in Models A-B), and the rest of Greece (in Model A), and increased over time in west Greece, Thessaly, and north Greece (in the latter case at decreasing rate) (in Model A).
- That the impact of L, the cost of E (in all Models), K (in Model A), the flow of investments (in Model B), and T_a (in Model D) varied across space.

As in the RE analysis, the model which is irreconcilable with the CD setting and, hence, does not fit well with economic theory (Model D) is empirically associated with the lowest R^2. In the other three models, the estimated input coefficients ─involving L and the variable associated with E (also, a good proxy for the active use of K_2) plus one other factor─ seem to add up to more than one in the rest of Greece; but may or may not add to less than one in the other regions. This suggests IRTS in the former region and unclear returns to scale in the other regions. Model C recalls a likely RE result by yielding a possible negative effect for K_1 in west Greece (the relevant p-value is 0.030). However, Model B is once again associated with the highest goodness of fit (91%) and more DoF vis-a-vis the other pooled data analyses carried out, so perhaps best captures and advances our understanding on how the country's agricultural production operated during the period in question. Consequently, in the following paragraphs we focus on the coefficients recovered via Model B.

According to the findings associated with p-values below 1%, *ceteris paribus*, a marginal increase in (a) L increased output in north Greece, west Greece and the rest of Greece outside Thessaly; (b) the energy bill increased output throughout the country; (c) capital investments for buildings and machinery brought output down in Thessaly, and in the rest of Greece outside the north and west country.[11] On the other hand, as mentioned in the beginning of the previous paragraph, Thessaly featured higher levels of MFP. In addition, the estimated input coefficients concerning Thessaly (the other three regions) add up to less (more) than one, which suggests the regional production function exhibited DRTS (IRTS).

[11] Conceivably due to upsets and interruptions needed for construction, assemblance, familiarization. The stock of capital is associated with an inferior fit. However, the stock of capital resurfaces as a highly relevant variable (also associated with a positive coefficient) once it is adjusted for price inflation.

Table 3. *OLS regressions with robust standard errors of pooled data on agricultural production across Greece, 2004-16*

	Explanatory variables	Model A log-log with a trend term	Model B log-log detrended	Model C log-log first differences	Model D first differences
1	Constant	9.898	9.547	0.023	476.387
2	Regions I-II (north Greece, west Greece)	ref.	ref.	ref.	
3	Region III (Thessaly)		0.464	ref.	
4	Region IV (rest of Greece)		ref.	ref.	
5	Regions III-IV	0.082			
6	Time trend in region I	0.058			
7	regions II-III	0.010			
8	region IV	0.000			
9	region I squared	-0.003			
10	Labor (in work units) in region I		2.545	-0.059	-1813.958
11	regions I, III	-0.141			
12	region II	0.414			
13	regions II-III			0.533	9601.630
14	regions II, IV		1.108		
15	region III		0.037		
16	region IV	1.605		1.394	23500.970
17	region I squared		-5.538		
18	region II squared	-3.441	-0.843		
19	Cost of energy in region I			0.502	5.068
20	regions I-II, IV	0.423			
21	regions I-IV		0.344		
22	regions II-III			0.190	1.582
23	region III	0.364			
24	region IV			0.593	8.900
25	region II squared	-2.745	-4.431		
26	region IV squared	3.559			
	Stock of capital (buildings & machinery) in				
27	regions I-II, IV	0.009			
28	region III	-0.723			
29	region III squared	3.900			
	Investments in buildings & machinery in				
30	regions I-II		-0.158		
31	regions III-IV		-0.322		
32	region IV squared		14.990		
33	Value of terrain in region I				0.043
34	region II				0.092
35	region III				0.029
36	region IV				0.091
37	Stock of buildings in regions I, III-IV			-0.150	
38	region II			-0.453	
	Observations (N)	52	52	48	48
	Model fitness (R^2)	87%	91%	49%	45%

Notes: The second regressor is linearly independent of the first regressor, the third regressor is linearly independent of the former two regressors, and so on. Regions that feature similar coefficients are grouped together so as to preserve DoF. All tests mentioned in Table 2 are carried out. When the Levin et al. (2002) test is considered the dependent variable in Models A and C-D turn out as non-stationary and all other variables of all Models turn out as stationary. When the Breitung (2001) and Hadri (2000) tests are considered the dependent variable in Models A turns out as non-stationary and all other variables of all Models turn out as stationary. When the Harris and Tzavalis (1999), Im et al. (2003) test are considered all variables of Models A-D turn out as stationary.

P-values per model (the parentheses specify lines): A: (5), (23), (28) 0.001; (12), (26) 0.003; (16) 0.005; (25) 0.006; (18) 0.027; (11) 0.412; (8) 0.912; (27) 0.948. B: (32) 0.040; (25) 0.047; (30) 0.544; (15) 0.833. C: (16) 0.001; (24) 0.021; (13) 0.029; (1), (38) 0.030; (22) 0.141; (37) 0.262; (10) 0.751. D: (34) 0.001; (24) 0.016; (13) 0.036; (36) 0.049; (1) 0.050; (33) 0.069; (22) 0.159; (10) 0.622; (35) 0.737. The rest are equal to 0.000.

Source: As in Table 1.

Table 4 provides a variant specification of Model B in a simple multiplicative (i.e., the usual extended CD) form associated both with more DoF, and a slightly lower R^2.[12] Again, the findings suggest E&T heterogeneity across space (higher in Thessaly), and that a marginal increase in capital investments for buildings and machinery brought output down output in Thessaly. At the same time: (i) a marginal increase in the energy bill increased output in Thessaly, (ii) a marginal increase in *L* increased output in the rest of Greece, and (iii) all regions operated under DRTS.

Table 4. *A variant of Model B resulting from an OLS regression with robust standard errors on detrended pooled agricultural production data in Greece, 2004-16*

	Explanatory variables	coefficients
1	Constant	9.791
2	Regions I-II, V	ref
3	Region III	0.193
4	Labor (in work units) in regions I-III	0.130
5	region IV	0.571
6	Cost of energy in region I	0.479
7	region II	0.294
8	region III	0.314
9	region IV	0.337
	Investments in build. & machin. in	
10	regions I-II, IV	-0.218
11	region III	-0.315
	Observations (N)	52
	Model fitness (R^2)	88%

Note 1: north Greece, west Greece, Thessaly, the rest of Greece correspond to regions 1-IV, respectively.
Note 2: The second regressor is linearly independent of the first regressor, the third regressor is linearly independent of the former two regressors, and so on. Regions that feature similar coefficients are grouped together. All tests mentioned in Table 2 are carried out. All variables are stationary.
Note 3: P-values (the parent-eses specify lines): (8) 0.001, (4) 0.016, (6) 0.047, (9) 0.072, (7) 0.268, (10) 0.314. The rest are equal to 0.000.
Source: As in Table 1.

Table 5. *A variant of Model B resulting from an OLS regression with robust standard errors on deflated pooled agricultural production data in Greece, 2004*-16

	Explanatory variables	coefficients
1	Constant	10.0141
2	Regions I-II, V	ref
3	Region III	0.366
4	Labor (in work units) in region I	2.492
5	region II	0.424
6	region III	0.219
7	region IV	1.038
8	region I squared	-5.268
9	Cost of energy in region I	0.296
10	regions II-III	0.257
11	region IV	0.390
	Deflated stock of machines in	
12	regions I-II, IV	0.073
13	region III	0.335
	Observations (N)	52
	Model fitness (R^2)	86%

Notes 1 and 2: As in Table 4.
Note 3: P-values (the pare-ntheses specify lines): (4) 0.001, (13) 0.003, (8) 0.007, (5) 0.013, (10) 0.014, (11) 0.036, (9) 0.089, (6) 0.155, (12) 0.313. The rest are equal to 0.000.
Source: As in Table 1.

Table 5 provides the best alternative in terms of model fitness when deflated values of *Q* and *K* are considered.[13] The squared value of an input –a feature of the translog expression− is maintained. Once again, the findings suggest E&T heterogeneity across space (higher in Thessaly). However, in this setting: (a) a marginal increase in *L* increases output, not only in the rest of Greece, but also in north Greece; (b) a marginal increase in K_2 increases output in Thessaly; (c) the north part of

[12] The adj. R^2 is 85%. In the previous case it was 88%.
[13] It is a specification in which the impact of price inflation is removed. The R^2 and DoF are slightly inferior to that of Table 4.

Greece, the west part of Greece, and Thessaly operate under DRTS, while the rest of Greece operated under IRTS.

5. Conclusions

The paper reveals considerable heterogeneity in agricultural production across Greece and advances our understanding on how the country's holdings operated at the regional level.

It turns out that during 2004-16, the average holding generally reduced the amount of labor used, and increased its output, capital, use of land, and the money paid for energy. As it shifted from a more to a less labor-intensive state of production, its labor productivity increased while its capital and land productivity, and the ratio of output over energy expenses decreased. In north Greece the average holding featured more machinery, higher labor productivity and more expenses for feeds, seeds, fertilizers and such inputs; in west Greece it featured higher valued land, higher land productivity and output over energy expenses, as well as capital productivity up to 2010; in Thessaly it featured higher labor productivity during 2004-06 and 2012-16; in Thessaly and in north Greece it featured more hectares and output, and energy expenses; in the rest of Greece it featured more labor, buildings, livestock, and carried out more investments in buildings and machinery; in Thessaly and the rest of Greece it featured higher capital productivity from 2011 on.

One of the models used (Model D) is both irreconcilable with the Cobb-Douglas production function framework, and empirically associated with the lowest goodness of fit. In contrast, the econometric analyses which are based on three translog functions (i.e., extended Cobb-Douglas or extended Cobb-Douglas-like models: i.e., Models A-C, and two variants of B) suggest that: (a) The impact of E&T and of factors not associated with the inputs (i.e., multifactor productivity) was, probably, higher in Thessaly (an outcome observed in Model B and its variants). (b) A marginal increase (reduction) in labor raised (reduced) output in the rest of Greece (the outcome was observed in all five models). (c) A marginal increase (reduction) in the energy bill and, probably, the use of energy raised (reduced) output in the north part of the country (models A-C) and Thessaly (Models A-B and one of B's variants). (d) Thessaly probably exhibited DRTS (Models B-C and B's variants). The former three findings imply that there was and, perhaps, there is still room for spatially differentiated interventions, and that the decline in agricultural output is reversible. In addition, they suggest that it might be sensible if E&T practices carried out in Thessaly were considered in other regions, and reductions (increases) in the cost of energy and in labor in agricultural production took place if they affected higher output increases (smaller output reductions) elsewhere in the economy. This said, the need for more specificity regarding individual activities and products will require different data and additional analyses.

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