Productivity analysis of pig farms in Greece in conjunction with their size

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Abstract

This paper studies the productivity of pig farms in conjunction with their size, in Greece. It is based on a research carried out on a sample of 80 pig farms located in various Greek regions. The economic results were derived from the collection and analysis of their technical and economic data and then classified according to the farm size. The contribution to the total output and the productivity of the factors of production used were analyzed with the use of the Cobb-Douglas production function. An attempt was made to explore the potential of increasing the total output, as well as the marginal productivity of the production factors used. This analysis yields very useful conclusions concerning the contribution of the production factors to the total product and some recommendations for their re-allocation in use.

Résumé

Cet article propose une étude portant sur la productivité des élevages porcins en Grèce sur la base de leurs dimensions. L'étude se base sur une recherche menée sur un échantillon de 80 élevages porcins situés dans plusieurs régions grecques. Les résultats économiques, issus de la collecte et de l'analyse des données techniques et économiques, ont été classifiés sur la base des dimensions des exploitations. La contribution à la production totale et la productivité des facteurs de production ont été analysées en utilisant la fonction de production Cobb-Douglas. On a essayé d'explorer l'accroissement potentiel de la production totale et la productivité marginale des facteurs de production utilisés. Cette analyse nous offre des conclusions très utiles portant sur la contribution des facteurs de production au produit total et des recommandations sur leur répartition.

1. Introduction

Pig farming is nowadays considered one of the most dynamic sectors of the Greek rural economy. This is apparent both from the total invested capital (over 293 million €), and from the overall production volumes (143,100 tons in 2000) (Batzios, 2001). In fact, pig farming accounts for approximately 25-30% of the total domestic meat production and covers about 50-60% of the total needs for consumption of pork meat; in addition, approximately 30000 people are employed in this sector Kitsopanidis, 1999). There are 927 pig farms in Greece (numbering over 20 sows), with a nominal capacity of 141,128 places for sows and their pigs (Ministry of Agriculture, 2001). Despite the improvements made over the recent years, pig-farming as a whole does present certain weaknesses, which can surely be attributed to the fact that pig-farming has only very recently been developed on a business level (Apostolopoulos et al., 1998).

There is a great scale of variation among Greek pig enterprises concerning housing design and structural considerations. These differences are related to the age of each farm's buildings, farm capacity, operational management techniques etc. In most of the farms with a capacity of a medium or large size, housing conditions generally contribute towards the satisfaction of pig husbandry and welfare requirements. Adversely, in small-sized farms these requirements are not met, thus leading to serious animal health and performance problems. Despite their low profitability, small-sized farms have been proved to be viable mainly because of their low operational costs (Papatheodorou and Papavasileiou, 1996). Most of the Greek pig enterprises were settled during 1970-1989 (85.44% of the total number) and, in particular, the farms with a relatively large capacity (on average 195 sows under production) were settled during the seventies. The number of sows in these farms was 75,915, which represented a percentage of 53.3% of the total Greek pig production. During the last decade or so, 141 pig farms (15.3% of the total number), consisting of 28,235 sows (19.8% of the total number of sows under production) have been updated. Besides, 47 enterprises with a total number of 4,850 sows under production have been relocated during 1991-1998, after the enforcement of the Greek Ministry of Agriculture guidelines which summarize farms' relocation and manure disposal policies according to public health preservation demands. It is a common sense that pig buildings in Greece are too old to satisfy the requirements for optimum pig production nowadays (Ministry of Agriculture, 2001).

2. Methodology

The research was conducted in the main pig-farming centers of Greece, namely the geographical regions of Attica, Voiotia and Evoia, Thessaly, Etoloakarnania, Macedonia, Thrace, Arta and Preveza. In these regions, 81,704 sows have been counted (58% of the total number of sows in Greece) (Ministry of Agriculture, 2001). The above-mentioned regions present a dynamic agricultural activity and an important primary animal feed production sector. A great

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number of plants producing animal feed mixes are grown in these regions and are used as a "guide" for determining the selling price of pork meat (Ridgeon, 1992; Galanopoulos, 1998). In general, it is believed that the variety of feeding conditions in these regions allows for a generalization of the study's results for whole Greece, with no significant divergence from reality. The data refer to the period 2000-2001 and were collected using specially structured questionnaires (Aggelopoulos, 2004).

The farms in the areas of interest were divided into 3 groups, based on the number of sows: M1 from 20 to199 sows, M2 from 200 to 399 sows and M3 from 400 sows and over. The sampling method used for the determination of the sample size was the analogical stratified sampling (Apostolopoulos et al, 2001). The sample (which accounts for 22.4% of the total number of farms of the above areas and 9% of the total number of farms in Greece) includes 43 farms from Thessaly (prefectures of Trikala, Larissa and Karditsa), 5 farms from Macedonia-Thrace (prefectures of Drama and Xanthi), 18 farms from Attica-Voiotia-Evoia and 14 farms from Etoloakarnania (Table 1).

Tab. 1. *Classification of the pig farms according to their size*

Prefectures	Size classes of sow herds (number of sows)					
	20-199 sows		200-399 sows		>= 400 sows	
	Total no. of farms	Sample size	Total no. of farms	Sample size	Total no. of farms	Sample size
Evoia	12	2	10	3	36	2
Trikala	78	14	8	3	24	3
Etoloakarnania	13	4	8	7	20	3
Larissa	22	9	11	5	17	2
Karditsa	10	4	5	1	7	2
Drama-Xanthi	12	3	5	1	6	1
Attica-Voiotia	24	4	18	3	12	4
TOTAL	171	40	65	23	122	17

SOURCE: Federation of Pig-farming Associations of Greece (1998)

The statistical analysis of the technical and economic data collected was made using the statistical package SPSS 11.5, and the economic results were calculated for the pig farms included in the sample. Following this, a productivity analysis was carried out, both for the total sample and for each size class of the farms. The productivity analysis was completed through the use of the Cobb-Douglas production function. The next step involved a calculation of the existing and optimum combination of the production factors used according to size of the farms.

The productivity analysis of the pig farms was carried out using the Cobb-Douglas production function. The aim of the analysis is to estimate the contribution of each production factor to the produced product, to calculate their marginal productivity and even the ratio to their using costs, to explore and improve their degree of utilization.

The Cobb-Douglas function was studied and empirically applied by numerous researchers producing satisfactory results (e.g. Zioganas et al., 1994; Katos and Batzios, 1988; Kim, 1986; Fulginiti and Perrin, 1998; Chand, 1986).

Through the application of this function, the relation between the production factors and the produced product is searched (Fulginiti and Perrin, 1998). The relation between given levels of productive factors in total and the amount of the produced product, using a given production technology, is mathematically expressed (Heathfield and Wibe, 1987) as follows:

$Y=f(X_1,X_2,.....X_n)$, where:

Y= product and $X_1,X_2,.....X_n$) = production factors.

With this function we can provide answers to questions concerning:

- whether the producers use the available production factors in a rational manner;
- the type of scale economies in the production.

By the estimation of the Cobb-Douglas function, we can determine the contribution of the used factors to the produced goods (pork meat) and calculate their marginal productivity (Zioganas et al., 1994; Katos and Batzios, 1988; Kim, 1986; Fulginiti and Perrin, 1998).

The productivity analysis refers both to the sample as a whole (i.e. the 80 pig farms selected) and to sub-samples by the size of the farms. The logarithmic (or power) function used is of the form:

$$Y= a X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4}$$

where:

Y=gross revenue in euros,

X_1=labour in euros,

X_2=livestock value in euros,

X_3=land, buildings and machinery as annual expenses in euros,

X_4=total feeding costs and a is a constant parameter to be estimated. These coefficients were selected because they are recognized as the main contributors when the operational cost of a pig enterprise is to be calculated (Kitsopanidis, 1999). In detail, it is generally accepted that animal feeding and fixed expenses (investment in buildings and equipment) are considered as the main finance charges, representing 57.4% and 22.3% of the total pig enterprise's operational cost, respectively (Kitsopanidis, 1999). Interestingly, labor costs, stock expenses and medications represent 8.3%, 5.7% and 6.3%, respectively.

The coefficients b1, b2, b3, b4 are parameters for estimation and constitute the elasticities of production in relation to the corresponding production factors, when all other production conditions are stable. The preconditions of this function are: the constant a must obey the restriction a>0 when the production elasticity bi is less than 1, i.e. the produced product never decreases but constantly increases without reaching a maximum, in accordance with the vari-

ation of the used production factor X_i. The sum of the production elasticities also indicates the type of returns to scale of the function (Heathfield and Wibe, 1987). More analytically:

if $\Sigma bi=1$, there are constant returns to scale,

if $\Sigma bi <1$, there are decreasing returns to scale,

if $\Sigma bi >1$, there are increasing returns to scale.

By returns to scale, we mean the degree of variation of the product, when the production factors levels vary by a continuous fixed proportion. In other words, if the production factor amounts increase by the same percentage, the product also increases at the same time to a lesser, similar or higher degree, then there are decreasing, constant or increasing returns to scale, respectively.

The increase in the overall product and in the marginal productivity of the production factors used can be achieved not only through the change of a single production factor, but also through the simultaneous change of all of them. This simultaneous alteration of the factors aims at identifying their optimum combination, under the specific terms of production.

Tab. 2. *Analysis of the marginal productivity of pig farms, for the whole sample and by size*

Production elasticities and marginal productivity	Total no. of units 80	Categories of size 20-199 sows 40	200-399 sows 23	>=400 sows 17
1. Production elasticity				
A) Labour costs	0.209[a]	-[o]	0.105[c]	0.200[c]
B) Livestock capital	0.478[a]	0.346[a]	0.112[c]	0.674[b]
C) Land, buildings and machinery (annual expenses)	0.288[a]	0.234[b]	0.082[c]	0.081[o]
D) Total feeding costs (value of animal feeds)	0.011[0]	0.185[c]	0.712[a]	-[o]
Sum of production elasticities (Σbi)	0.986	0.736	1.011	0.783
R (correlation coefficient)	0.988	0.974	0.963	0.961
R^2 (multiple determination coefficient)	0.977	0.948	0.927	0.924
2. Marginal productivity				
A) Labour (€/ hour)	9.2	-	4.30	15.6
B) Livestock capital (€ / €)	2.65	2.19	0.616	3.644
C) Land, buildings and machinery (annual expenses) (€/€)	1.28	0.99	0.49	0.36
D) Total feeding costs (value of animal feeds) (€/€)	0.20	1.33	1.20	-
3. Real cost				
A) Labour (€/ hour)	2.93	-	2.93	2.93
B) Livestock capital (€ / €)	1.17	1.17	1.17	1.17
C) Land, buildings and machinery (€/ €)	2.22	2.22	2.22	2.22
D) Total feeding costs (value of animal feeds) (€/€)	1.12	1.12	1.12	1.12
4. Ratio of marginal productivity & real cost				
A) Labour	3.13	-	1.46	5.32
B) Value of livestock capital	2.26	1.87	0.52	3.11
C) Land, buildings and machinery (annual expenses)	0.57	0.44	0.22	0.16
D) Total feeding costs (value of animal feeds)	0.17	1.18	1.07	-

Probability level at t: a) 0,000<p< 0,001, b) 0,001 <p< 0,01, c) 0,01<p< 0,05, o) p> 0.05 non statistically significant

The optimum combination of the production factors is at that point where the greatest possible gross income is reached with the same overall costs. This optimum is achieved, when the marginal productivities provide the same ratio to the cost unit of the factors used, which are included in the Cobb-Douglas function. The optimum combination gives the relation, according to which any transformation of one factor into another is economically less profitable. The optimum combination can also be called a combination of minimum cost, since it achieves the lowest possible cost per gross income unit. The optimum combination of the production factors is based on this overall cost, but is attained through various combinations of the former (Kitsopanidis and Kamenidis, 1992; Zioganas, 1982).

The formula of the optimum or minimum cost combination can be written as follows:

$b_1/X_1= b_2/X_2=.....= b_n/X_n$, where:

$b_1, b_2,..., b_n$, are the values of the production elasticities; and,

$X_1,X_2...,X_n$,, are the annual expenses of the factors included in the production function. It is worth noting that when capital is expressed in the function as total value and not as annual expenses (e.g. livestock value), then this factor must be expressed in annual expenses in the optimum combination formula. We then estimate the existing and optimum combination of the production factors as follows.

3. Results

More specifically, the Cobb-Douglas function is applied here in each case as follows (table 2):

i) Total number of the farms in the sample

The estimated function is:

$$Y=2.732\ X_1^{0.209}\ X_2^{0.478}\ X_3^{0.288}\ X_4^{0.011}$$

The sum of the production elasticities (_bi=0.986) indicates rather decreasing returns to scale, which explains some intensification in the production of pork meat. The correlation coefficient (R=0.988) between the dependent variable and the independent variables is very high and has as a result a high multiple determination coefficient (R2=0.977). This coefficient shows a very high degree (97.7%) of dependence of the gross income variation due to the production factors used.

The individual production elasticities indicate that the contributions to the formulation of the end-product, in order of importance, are: livestock 47.8%, land and permanent equipment 28.8%, labour 20.9% and animal feeds 1.1%. Obviously, the share of animal feeds in the formulation of the end-product is very small.

The marginal productivity of labour covers the cost of its use, as can be seen in the ratio between marginal productivity and real cost (3.13). This means a very productive use of labour.

Tab. 3. *Existing and optimum combination of production factors for all farms*

Existing and optimum combination of production factors	Gross income (euros)	Composition of production factors			
		Labour costs (euros)	Livestock capital (annual expenses) (euros)	Land, buildings and machinery (annual expenses) (euros)	Feeding costs (euros)
1. Existing combination	805204.97	26078.11	54658.06	190775.39	59210.37
2. Optimum combination	1301271.19	70102.31	160329.70	96600.32	3689.59
3. Change % (+ or -)	+61.6	+168.8	+193.3	-49.3	-93.7

The marginal productivity of livestock is high, as can be seen in the ratio between marginal productivity and real cost (2.26). This indicates a productive use of this factor.

The marginal productivity of land, buildings and machinery is low in comparison to the real cost, as can be seen in the ratio between the two (0.57). This indicates a non-productive use of this factor.

The marginal productivity of the animal feeds is low in comparison to the real cost, as can be seen in the ratio between them (0.17). This also indicates a non-productive use of this factor.

In the case of a simultaneous variation of all production factors, the optimum combination suggests a significant increase in labour (by 168.8%) and livestock (by 193.3%), and a reduction of land, buildings and machinery (by 49.3%) and feeding costs (by 93.7%), (Table 3). As a result a high increase (61,6%) of the gross income follows. However, all these changes do not seem very realistic in practical terms, as they are very high and difficult to be specified at farm level.

ii. Size ranging from 20 to 199 sows (M_1)

The estimation of the function is:

$$Y=5.740\ X_1^{0}\ X_2^{0.346}\ X_3^{0.234}\ X_4^{0.185}$$

The sum of the production elasticities (Σbi=0,765) indicates decreasing returns to scale, which means a high intensification of production. The correlation coefficient (R=0.974) between the dependent variable and the independent variables is very high and decides an equally high multiple determination coefficient (R2=0.948). This coefficient shows that the variation in the product depends by 94.8% on the variation of the above-mentioned production factors.

The individual production elasticities indicate that the contributions to the formulation of the end product, in order of importance, are: livestock 34.6%, land and permanent equipment 23.4% and animal feeds 18.5%. The elasticity of labour is statistically non-significant and therefore the share of labour in the formulation of the end- product and its marginal productivity are not taken into account, as they are unreliable estimates.

As we can see from the ratio between marginal productivity and real cost (1.87 and 1.18 respectively), there is a productive use of livestock and animal feeds. On the contrary, there is a non-productive use of land, buildings and machinery (the ratio between marginal productivity and real cost is 0.44).

If there is a simultaneous variation of all production factors, the optimum combination suggests a reduction of labour (by 40.9%) and feeding costs (by 56.3%), and an increase in livestock (by 144.9%) and in land, buildings and machinery coefficient (by 52.7%). The recommended variations are rather unrealistic and therefore the expected increase in gross income by 40.4% bears no particular significance (Table 4), for similar reasons as above.

iii. Size ranging from 200 to 399 sows (M_2)

Tab. 4. *Existing and optimum combination of production factors for the farms with 20-199 sows*

Existing and optimum combination of production factors	Gross income (euros)	Composition of production factors			
		Labour costs (euros)	Livestock capital (annual expenses) (euros)	Land, buildings and machinery (annual expenses) (euros)	Feeding costs (euros)
1. Existing combination	148576.02	10727.80	28302.64	29461.86	92582.26
2. Optimum combination	208741.29	6331.21	69337.58	45016.97	40388.80
3. Change % (+ or -)	+40.4	-40.9	+144.9	+52.7	-56.3

The estimated function is:

$$Y=1.054\ X_1^{0.105}\ X_2^{0.112}\ X_3^{0.082}\ X_4^{0.712}$$

The sum of the production elasticities (Σbi=1,011) indicates rather constant returns to scale. The correlation coefficient (R=0.963) between the dependent variable and the independent variables is very high and prodives an equally high multiple determination coefficient (R2=0.927). This coefficient shows that the variation in the product depends by 92.7% on the variation of the production factors.

The individual production elasticities indicate that the contributions to the formulation of the end product, in order of importance, are: animal feeds 71.2%, livestock 11.2%, labour 10.5%, and land and permanent equipment 8.2%.

It is evident that the share of land and permanent equipment in the formulation of the end-product is the lowest among the independent variables.

As can be seen from the ratio between marginal productivity and real cost (1.46 and 1.07 respectively), there is a productive use of labour and animal feeds. On the contrary, there is a non-productive use of livestock and land, buildings and machinery (the ratio between marginal productivity and real cost is 0.52 and 0.22 respectively).

For a simultaneous variation of all production factors, the optimum combination suggests an increase in labour (by

Tab. 5. *Existing and optimum combination of production factors for farms with 200-399 sows*

Existing and optimum combination of production factors	Gross income (euros)	Composition of production coefficients			
		Labour costs (euros)	Livestock capital (annual expenses) (euros)	Land, buildings and machinery (annual expenses) (euros)	Feeding costs (euros)
1. Existing combination	590575.12	38797.28	31108.50	88331.49	324114.49
2. Optimum combination	603197.5	50646.93	48717.53	39552.84	343434.46
3. Change % (+ or -)	+2.13	+30.54	+56.60	-55.2	+5.96

30.54%), livestock (by 56.60%) and feeding costs (by 5.96%), along with a reduction of land, buildings and machinery (by 55.2%). The recommended variations show an increase in gross income by only 2.13% (Table 5). These changes seem to be rather reasonable to be achieved in practice, as they are not so high to be implemented.

iv) Size ranging from 400 sows and over (M_3)

Due to the small number of farms in this size category, a rather not reliable function is estimated; however the relevant results are presented in Table 2. For a simultaneous variation of all production factors, the optimum combination suggests a major increase in labour and livestock (by 371.7% and 360.6% respectively) and reduction in land - buildings - machinery, and feeding costs (by 53.5% and 65.2% respectively), resulting in an extremely high increase in income (by 330,5%). This solution is rather unrealistic, since the proposed changes cannot be easily implemented (Table 6).

4. Conclusions and recommendations

This paper has studied the contribution of the production factors to the product of pig farms in Greece according to their size. It has been shown that there is a high degree of dependence of the gross income variation on the production factors. More specifically, the main findings are as follows.

For all farms in the sample the marginal productivity of labour and livestock factors was found to be high, whereas that of land and permanent equipment and animal feeds was found relatively low. For the small-sized farms the marginal productivity of livestock and animal feeds was high, whereas that of land and permanent equipment was relatively low. For the medium-sized farms the marginal productivity of labour and animal feeds was found high, whereas that of land and permanent equipment and livestock factors was found relatively low.

For the total number of farms in the sample, the contribution to the formulation of the end-product, by order of importance, is related to livestock, land and permanent equipment, labour and animal feeds. For the small-sized farms, the contribution to the formulation of the end-product, by order of importance, is related to livestock, land and permanent equipment, animal feeds and labour. For the medium-sized farms, the contribution to the formulation of the end-product, by order of importance, is related to animal feeds, livestock, labour and, finally, land and permanent equipment. For the large-sized farms, the contribution to the formulation of the end-product, by order of importance, is related to livestock, labour, land and permanent equipment, and animal feeds; the share of the last two factors is quite small.

Searching the variation of all production factors, concerning the total number of farms in the sample, the optimum combination suggests a significant increase in labour and livestock, and a reduction of land and permanent equipment, and feeding costs. In this way the maximization of the gross income can be approximated.

Savings related to animal feeding outlay are of great importance, since this factor contributes the most in total operational cost of a pig enterprise. Knowledge of the accurate nutritional needs of pigs according to the different stages of their life cycle and formulation of well-balanced and cost-effective diets under appropriate and adequately controlled mixing procedures, will reassure an optimum animal performance, additionally contributing towards a clear economic advantage for the producer. Accordingly, the use of genetic material is judged necessary and, therefore, the financing of a renewal program on the existing genetics of sows will lead to the exploitation of the factor "animal chapter". Another worth mentioning characteristic of pig farming in Greece is the old building facilities and the old mechanical equipment. Hence, it is important to promote the financing of modernization of pig farms that will lead to the increase of productivity, reduction of cost of production and improvement of work conditions of pig-breeders.

Tab. 6. *Existing and optimum combination of production factors for farms with 400 sows and over*

Existing and optimum combination of production factors	Gross income (euros)	Composition of production coefficients			
		Labour costs (euros)	Livestock capital (annual expenses) (euros)	Land, buildings and machinery (annual expenses) (euros)	Feeding costs (euros)
1. Existing combination	916990.29	44155.29	75313.11	181471.16	518581.31
2. Optimum combination	3948518.21	208317.6	346903.1	84278.02	180022.08
3. Change % (+ or -)	+330.5	+371.7	+360.6	-53.5	-65.2

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