ANALYSIS OF THE TECHNICAL EFFICIENCY OF THE MEAT INDUSTRY IN ARAGON (*)

LUIS PEREZ Y PEREZ - MARIA LUISA FEIJÓO BELLO (**)

Abstract

The agro-food system, as a part of the overall economy, is more significant in Spain than on the average in the rest of the European Community. Aragon is an important agricultural region and the agro-food industry is the second industrial sector of its economy.
There are two objetives in this paper. Firstly, to analyse relationships between the agro-food industry with the rest of the agro-food system in Aragon, using the last regional Input-Output tables. Results show that the meat industry is the branch with the greatest potential influence in the agro-food system in the region.
The second objetive is to analyse production and technical efficiency in the Aragon meat industry. A deterministic Cobb-Douglas frontier has been estimated using corrected ordinary least squares regression. Technical efficiency has been analysed using Timmer and Kopp measures.

Résumé

Le système agro-alimentaire, comme étant une composante de l'économie globale, est plus important en Espagne par rapport à la moyenne du reste de la Communauté Européenne. Aragon est une région agricole de grande gravité et l'industrie agroalimentaire représente le deuxième secteur industriel de son économie.
Le présent travail a deux objectifs. En premieur lieu, analyser les relationns entre l'industrie agroalimentaire avec le reste du système agroalimentaire, moyennant les derniers tableaux régionaux d'input-output. Les résultats montrent que l'industrie de viande est la branche ayant le plus d'influence potentielle dans le système agroalimentaire dans la région.
Le deuxième objectif réside dans l'analyse de la production et de l'efficacité technique pour l'industrie de viande en Aragon. Une frontier déterministique Cobb-Douglas a été estimée moyennant une régression aux moindres carrés corrigés. L'efficacité technique a été analysé avec les coefficientes de Timmer et de Kopp.

The Agro-Food System (AFS) makes up an important part of the economy. The agro-food industry (AFI), as part of the AFS, is particularly important due to its contribution to the creation of wealth and economic development.
In Spain, from the productive point of view, the AFI is the most import industrial sector. In 1990, gross production made up 19.1% of total industrial production and 16.3% of total employment in industry (INE, 1993). In the Aragon region, the AFI is not very developed; the weight of employment and gross production is lower than the national average at a 13.9% of the total industrial production and 12.6% of industrial employment in the region.
This paper is made up of two parts. The first part analyses the structure of the AFI in its demand relationships with the rest of the Aragonese AFS.
The economic relations between agriculture and the AFI are determined using Input-Output techniques.
If the meat industry is an element of economic development in Aragon, the second part concentrates on analyzing the production and technical efficiency of this industry. An econometric analysis of data obtained through surveys has been carried out. A Cobb-Douglas production function is estimated and the technical efficiency of the sector is studied using the Timmer index.

Methodology

The Input-Output analysis

The first applications of the Input-Output analysis were made in order to analyze the links of interdependencies between the economic sectors.
According to Leontief, the aim is to analyze and measure the existing relationship between the different sectors from an economic system.
From this Leontief inverse matrix, some indicators of the sectorial dependence in the economic system are deduced taking the final demand as reference.
The Leontief inverse matrix is defined by the expression $[I-A]^{-1}$, where A is the technical coefficients matrix and I the identity matrix. Each A_{ij} element of the matrix indicates the necessary quantity of the product from sector i so that sector j can supply a quantity of their products for final use.
Using the lead diagonal of the Leontief inverse matrix, the total increase in production of a sector can be measured with the increase of one unit of its final demand.
The sum of elements of a column in this matrix expresses the increase of the total regional output as a consequence of the variation of a monetary unit in the final demand of the sector corresponding to the column. This is interpreted as the multiplier coefficient of a particular sector within the economy.
The sum of elements along the row of this matrix measures the increase in the regional production of the sector, caused by the variation of one unit in the final demand of each and every one of the sectors which make up the economy.
This is an output multiplier which quantifies the impact of the whole economy on a particular sector.
The analyses are based on the latest Input-Output tables (IOT) of Aragon and refer to the year 1985 (Ibercaja, 1990). In the analysis of AFS, sectors 1 to 3 have been used. (agriculture, livestock, forestry and fisheries) and together with 23 and 30 corresponding to AFI.

The frontier production function

There is no unanimity of criteria in order to determine the method to be used in the estimation of the frontier production function.
Therefore, the choice of estimation methods is linked to the objective of the study and to the characteristics of the desired efficiency measures. (Bravo-Ureta, 1986). A revision of the different forms of estimation can be seen in Alvarez Pinilla (1991).
Russell and Young (1983) said that «there would seems to be a consensus in the recent literature on production functions that it is the production function rather than some fitted average function which corresponds to the theoretical notion of the production function».
We adapted their proposal, also used by Murua (1990) which consisted of the econometric estimation of the frontier function, capable of offering individual measures of efficiency for each observation, together with the group average subject to statistical analysis.
The frontier production function to estimate adapts the following general form.

$$y = f(x) = (x_1, x_2, \ldots, x_i)\, e^{\epsilon},\ \epsilon,\ \epsilon \leq 0 \quad (1)$$

and in the Cobb-Douglas form,

$$y = a x_1^{\alpha} x_2^{\beta}, \ldots, x^{\varrho}$$

(*) A previous version of this paper has been presented at the VIIIth Congress of the European Association of Agricultural Economists.

(**) Servicio de Investigación Agraria - Gobierno de Aragón, Zaragoza.

$$\log y = a + \alpha \log x_1 + \beta \log x_2 + \ldots + \varrho \log x_i + \epsilon,\ \epsilon \leq 0 \quad (2)$$

The random disturbances (ϵ) are assumed to follow a one-sided distribution and to be independently and identically distributed. In addition, the set of inputs (x_i) are assumed to be independent of the disturbances.
Function (2) has been estimated using corrected ordinary least squares (COLS) regression. That is, as a first step, ordinary least squares (OLS) is applied to (2), yielding best linear unbiased estimates of the α, β, ..., ϱ coefficients.
The intercept estimated is then corrected by shifting the function until no residual is positive and one is zero.
The data set has been derived from a survey of the meat industries carried out in 1992. A stratified random sample has been used and, among 117 meat companies in Aragon, 39 have surveyed. In this cross section survey the Gross Added Value (GAV) is the dependent variable and labour (L) and capital (K) the independent variables.
Technical efficiency has been calculated following the argument introduced by Farrell (1957), dividing efficiency into technical and allocative efficiency.
Technical efficiency for these industries has been analysed using the Timmer (1971) measure.

Analysis of results

The Leontief matrix

Analyzing the Leontief inverse matrix of regional coefficients, one can appreciate that the sector with the greatest potential impact is the meat industry, presenting a coefficient of 2.17, which means that in order for the meat industry to produce one unit of final demand, the whole regional economy must produce 2.17 units (**table 1**).
The greatest potential influence does not necessarily mean profitability of the investments or an increase in employment. Even if this multiplier is high, this does not mean that the investments in it are particularly profitable or that they are going to create more employment. This potential influence implies that the meat industry is the sector most closely related to the others so that its input supply is very diversified and furthermore, this demand is mostly satisfied by regional supply.
Livestock appears in second place, followed by the dairy, wine and animal feeds industries. The remaining sectors have a lower than average impact. Agriculture and forestry hold the lowest positions which indicates the low importance of both when facing an increase in supply at a regional level.
The potential influences are not generated uniformly throughout all sectors. The influence exerted by the increase of one unit of the final demand of the meat industry would be divided between the increase of its own production and the increases in livestock, agriculture and the animal feeds industry. The meat industry in Aragon would have a cover percentage of 99.4% if there were an increase in the final demand (**table 2**).
One must point out that agriculture appears in all sectors as a passive element, since its influence is notably weaker than the other sectors (1.11) in spite of being the basis of the whole group.
Just as with the influence effects, on studying the multipliers by rows of the Leontief inverse matrix, one can observe that not all sectors have the same impact on the output of a particular sector (**table 3**).

Table 1 ***Multiplier coefficients for sectors in the AFS.***

	Multiplier Coefficients
Meat industry	2.17
Livestock	1.52
Dairy	1.46
Wine	1.41
Animal feeds	1.41
Other foods	1.33
Milled products	1.28
Juices and canned vegetables	1.20
Other beverages	1.16
Agriculture	1.11
Forestry	1.01

Source: Input-Output Table of Aragon.

Table 2 ***Multiplier coefficients of the meat industry.***

		Multiplier Coefficients
Meat industry		1.15
Livestock		0.68
Agriculture		0.16
Animal feeds		0.16
	Sum	2.16
	Impact	2.17
	Cover percentage	99.4%

Source: Input-Output Table of Aragon.

Table 3 ***Impact of the AFS sectors.***

	Multiplier Coefficients
Agriculture	2.96
Livestock	2.13
Animal feeds	1.53
Meat industry	1.15
Other foods	1.14
Milled products	1.08
Wine	1.03
Forestry	1.03
Other beverages	1.02
Dairy	1.00

Source: Input-Output Table of Aragon.

Agriculture and livestock sectors hold the leading positions. Their multipliers indicate the total economic effort when the final demand of each of the remaining sectors increases by one unit.
The animal feeds industry and the meat industry both stand out within the AFS although the index is not significantly different between all sectors, which confirms the high degree of interdependence between all the Aragonese agro-industrial sectors. The animal feeds and meat industries hold the highest position within agro-industry. The effects upon these two sectors of the increase in regional production are very important.

The estimated function and technical efficiency measures

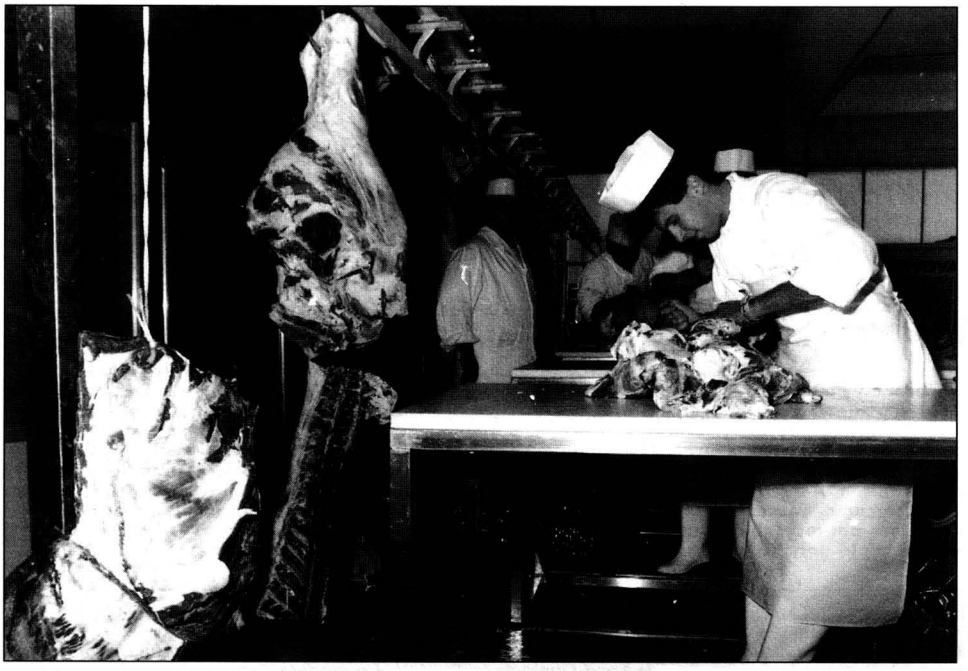
The Cobb-Douglas production function has been specified in the following manner:

$$\log GVA = a + \epsilon \log L + \epsilon \log K + \epsilon$$

where GVA represents the added value (production value - value of raw materials and external services - energy expenses); L represents the work factor (number of employees) and K are the payings-off by the industry as a proxi variable of the capital. a is the ordinate at origin and ϵ is the random disturbance. α and β are the partial elasticities of production with regard to labour and capital respectively.
One of the problems we have encountered has been the influent observations (Peña, 1986). These are characterized by their being very heterogeneous compared to the rest of the sample, which poses some problems for the estimation of the production frontier.
This frontier should represent the best practice with a technology which is common to the industries included in the sample. Therefore all atypical observations have been eliminated. The process concluded by eliminating 3 observations, the final model thereby being estimated with 36.
The average production function estimated by the OLS method is the following:

$$\log GVA = 5.373 + 0.466\ L + 0.516\ K$$
$$(5.70) \quad (2.68) \quad (3.61)$$
$$R^2 = 0.6544 \quad F = 34.137 \quad D-W = 1.999$$
$$\alpha + \beta = 0.983$$

The values in brackets are the t statistic, which has statistical significance at a level of 5%. The F statistic indicates that the global adjustment is significant at 5% and the variables included in the model explain 65.4% of the variations in production. The adjusted determination coefficient (R^2) is considered to be quite good for estimates obtained with cross-section data.
The Durbin-Watson (D-W) value indicates that there is no autocorrelation between the residuals (ϵ). In order to detect the non-existence of heterokedasticity, the Breush-Pagan test has been applied, thus confirming the homokedasticity hypothesis.



The signs of the regression coefficients are those expected. The L and K variables have a positive relationship with the dependent variable (GVA).
One can deduce from the results of these estimations that the Aragonese meat industry production process is slightly more intense in the use of capital (0.51) than in labour (0.46).
Once the average production function has been estimated, in order to obtain the frontier production function, we must use the maximum positive residual. In our case, the maximum positive residual is 1.390 which, added to the constant, produces a shift of the estimated function giving rise to the frontier production function.

$$\log GVA^* = 6.763 + 0.466\ L + 0.516\ K$$

$$GVA^* = 865.32\ L^{0.466}\ K^{0.516}$$

where GVA* represents the maximum level of output for this level of use of inputs. For each observation Timmer's technical efficiency measure relates the output really produced with that potentially obtainable at the frontier taking into account the level of inputs used.
The measure referring to each industry is given by the ratio of the real output compared to the respective frontier output (**table 4**).
The ($\epsilon_i \leq 0$) residual is the deviation with respect to the efficient production and represents the measure of inefficiency.

$$\epsilon_i = \log GVA - \log GVA^* \quad i = 1, \ldots, 36$$

$$\text{Timmer } TE_i = \exp(\epsilon_i) = GVA/GVA^* \leq 1$$

The estimated function represents constant scale returns ($\alpha + \beta$) = 0.983. In this case the Timmer and Kopp efficiency measures are identical, which is why only the Timmer measure was used for this analysis.

Table 4 ***Timmer technical efficiency measure (TE) for the meat industry in Aragon.***

OBS	TE	OBS	TE	OBS	TE
1	0.834	13	0.903	25	0.934
2	0.892	14	0.886	26	0.896
3	0.895	15	0.971	27	0.861
4	0.897	16	0.894	28	0.850
5	0.862	17	1	29	0.879
6	0.974	18	0.969	30	0.866
7	0.828	19	0.875	31	0.891
8	0.893	20	0.832	32	0.931
9	0.843	21	0.948	33	0.883
10	0.864	22	0.838	34	0.943
11	0.851	23	0.850	35	0.995
12	0.922	24	0.615	36	0.909
Average:	0.888				

The technical efficiency average measure is 0.888 (the minimum value is 0.615), which indicates that with both the input levels and the capital and labour levels given, the GVA could be increased by 12%. 52.7% of the industries present an over average efficiency and 77.7% higher than 0.85.

Final remarks

In Aragon, the meat industry is the sector of the agro-industry which has the greatest influence in the AFS. It is however the sector of activity most related to others of the regional AFS. Its provision of intermediate outputs is very diversified and its demand for inputs is covered by regional supply. The meat industry is very much dependent upon the Aragonese agricultural sector.
The influence exerted by the meat industry, in its final demand, would produce increases in its own production, followed by increases in livestock, agriculture and animal feeds industry.
The Cobb-Douglas production function estimate of the meat industry presents an elasticity of capital (0.51) which is greater than the labour elasticity (0.46). This means that the Aragonese meat industry uses more intense production processes in capital than in labour.
The analysis of technical efficiency indicates the possible saving in use of both productive factors. The Timmer measure, even though it refers to a single period of time and has a limited informative capacity, does indicate that, given the present use of technology and labour in the Aragonese meat industry, if the detected inefficiency was eliminated, the added value could be increased by as much as 12%. However, 52.7% of the industries detect an over average efficiency. ●

References

Alvarez Pinilla A. 1991. «*Análisis económico de la eficiencia de las explotaciones lecheras en Asturias*». Ph D. Thesis. Universidad de Oviedo. 142 pp.
Bravo-Ureta B.E. 1986. «Technical efficiency measures for dairy farms based on probabilistic frontier function model». *Canadian Journal of Agricultural Economics*, Vol. 34 (3), 399-415.
Farrell M.P. 1957. «The Measure of productive efficiency». *Journal of the Royal Statistical Society*, 120, 253-290.
Ibercaja, 1990. *Estructura productiva de la economía aragonesa 1985. Tablas Input-output*. Ibercaja. Servicio de estudios. Zaragoza, 331 pp.
Instituto Nacional de Estadística (INE), 1993. *Encuesta Industrial 1987-1990*.INE. Madrid. 350 pp.
Kopp R.J., 1981. «The measurent of productive efficiency: a reconsideration». *Quaterly Journal of Economics*, 97, 477-503.
Murua J.R. 1990. «*Coordinación y eficiencia de la producción porcina en Aragón*». Ph. D. Thesis. Universidad del Pais Vasco. 280 pp.
Peña D. 1986. «Observaciones influyentes en modelos econométricos». *Investigaciones Económicas*. Vol. XI (1), 3-24.
Russell M.P., Young T., 1983. «Frontier production functions and the measurement of technical efficiency». *Journal of Agricultural Economics*, 34, 139-149.
Timmer C.P., 1971. «Using a probabilistic frontier function to measure technical efficiency». *Journal of Political Economics*, 79, 776-794.