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MEASUREMENT OF THE TOTAL FACTOR PRODUCTIVITY OF SPANISH AGRICULTURE: 1962-1989

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ABSTRACT

The agricultural sector in Spain has undergone rapid transformation since the 1960s. Rapid increases in capital and chemical input use was accompanied by rapid decreases in labor use. This study reports the first calculations for total factor productivity (TFP) growth for Spanish agriculture. TFP calculations are made for the crops and livestock sector for the 1962-1989 period. During the 1962-1970 period, TFP growth was 1.84 percent per year. From 1970 to 1980 TFP grew a 3.44 percent, one of the highest rates for the agricultural sector achieved in the world during this period. TFP growth slowed in the 1980s. This appears to be related to Spain's entry into the European Common Market in the 1980s. Greece experienced a similar TFP slowdown in this period.

KEY WORDS: Productivity, Spain, Agriculture

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MEASUREMENT OF THE TOTAL FACTOR PRODUCTIVITY OF SPANISH AGRICULTURE: 1962-1989

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1. INTRODUCTION

Spain's agricultural sector has undergone a substantial transformation during the last three decades. Rapid urbanization after 1960 produced a decrease in agricultural labor increasing rural salaries. In addition, higher income levels altered the composition of food demand implying a reorganization of the agricultural production to high-income products, such as meat, dairy and fruits. In response to this new environment, producers adopted new technology in the form of intermediate inputs, machinery and new practices and services, and intensified the area under production through irrigation. Farm size also increased during the period.

The model that Spain adopted to develop the agricultural sector was based primarily on foreign technology in the form of direct imports - seed, plants, animal and machinery - and information transfers. This import of technology was accompanied by a program of local research and adaptations. It has been argued that this model of technical change, based on agricultural intensification and widespread introduction of foreign technology, showed signs of exhaustion at the beginning of the 1980s (Herruzo and Echeverría, 1993).

The objective of this paper is to examine the change in total factor productivity (TFP) of Spanish agriculture since the 1960s to evaluate the performance of Spain's agriculture. We also intend to ascertain the capacity of the model of technical change followed in the previous years to carry Spanish agriculture through the new and more competitive environment stemming from EC membership and GATT negotiations.

The two approaches to TFP measurement: the growth accounting approach and the econometric approach, are useful and should be considered appropriate (Antle and Capalbo, 1988 p.63). The first one uses index numbers measures of TFP, alternatively econometric methods estimates TFP changes using production, costs, and profit functions. Both approximations are linked through production theory. A previous study of agricultural TFP in

Spain was completed by San Juan (1986). It covered the years 1964-1980 and it was based in Solow (1957). This econometric method assumes a Cobb-Douglas production technology. San Juan study does not differentiate between crop and livestock sectors. But within a multifactor productivity framework, it is insightful to split agricultural production into two major sectors: crop and livestock (Evenson, 1992).

This paper uses a discrete time interval index developed by Tornqvist to approximate the continuous time internal Divisia index for outputs, inputs and TFP for crop and animal production over the period 1962-1989. Section 2 outlines the theoretical framework for TFP measures. Section 3 presents the data used for measurement of TFP in the Spanish agricultural sector. Finally the empirical results of TFP measurement are reported, and trends in TFP in Spain are compared with those of other European countries in similar periods.

2. THEORETICAL FRAMEWORK

There are two formal procedures for deriving TFP indexes: from an economic accounting measure, and from a production function or from the cost function associated with the production function. The relation can also be derived from the output supply and factor demand equations associated with the profits function. These measures are equivalent to economic accounting measures, which are based on index number theory. (Evenson, Landau and Ballou, 1987 p.1).

The accounting derivation of the TFP index is straight forward. Suppose that an economic sector is in long run equilibrium:

$$\sum_i P_i Y_i = \sum_j R_j X_j \qquad (1)$$

where Y_i are outputs with prices P_i, and the X_i are inputs with prices R_i. Quasi-fixed factors such as land or buildings are treated as having a "rental" or service price. Now differentiate (1) totally with respect to t:

$$\sum_i Y_i \frac{\partial P_i}{\partial t} dt + \sum_i P_i \frac{\partial Y_i}{\partial t} dt = \sum_j X_j \frac{\partial R_j}{\partial t} dt + \sum_j R_j \frac{\partial X_j}{\partial t} dt \qquad (2)$$

This expression is exact for infinitely small changes. For discrete or finite changes index number problems must be dealt with.

Divide the left-hand side of (2) by $\Sigma P_i Y_i$, and the right-hand side by $\Sigma R_j X_j$, the two sums are equal. Then multiply the first term of (2) by P_i/P_i, the second by Y_i/Y_i, the third by R_j/R_j, and the fourth by X_j/X_j. Note that $Y_i P_i/\Sigma P_i Y_i = S_i$ the output share of the ith output, and $X_j R_j/\Sigma R_j X_j = C_j$, the input cost share of the jth input. Let $\hat{x}_j = \frac{1}{X_j}\frac{\delta X_j}{\delta t}dt$ be a rate of change. This produces:

$$\sum_i S_i \hat{P}_i + \sum_i S_i \hat{Y}_i = \hat{p} + \hat{y} = \sum_j C_j \hat{R}_j + \sum_j C_j \hat{X}_j = \hat{r} + \hat{x} \qquad (3)$$

where $\hat{p}$, $\hat{y}$, $\hat{r}$ and $\hat{x}$ are now rate of change of aggregate output prices, output quantities, factor prices and factor quantities respectively. The rate of change in total factor productivity $\hat{T}$ is now defined as:

$$\hat{T} = \hat{y} - \hat{x} = \hat{r} - \hat{p} \qquad (4)$$

the motivation for this definition is that it captures efficiency gains.

The basic TFP postulated in (4), and other version derived require an index number to aggregate outputs, inputs and prices.

In this paper the commonly-used Tornqvist-Theil TFP quantities indices are computed. It is written in logarithms as:

$$Ln\ (Y^t/Y^{t-1}) = \sum_i \frac{1}{2}(S_i^t + S_i^{t-1})\ Ln\ (Y_i^t/Y_i^{t-1}) \qquad (5)$$

$$Ln\ (X^t/X^{t-1}) = \sum_j \frac{1}{2}(S_j^t + S_j^{t-1})\ Ln\ (X_j^t/X_j^{t-1}) \qquad (6)$$

which is the ratio of two successive input (or output) quantities weighted by a moving average of the share of the input (or output) in total cost (or revenue)[1]. The Theil-Tornqvist index is a discrete approximation to a Divisia index (Diewert, 1976). Also it is the appropriate index when technology is linear homogeneous translog (either for the production function, or its dual, the cost function or the profit function) (Diewert, 1981). In addition, the translog function is a "flexible" function form in the sense that it is a second order approximation to any arbitrary production, cost or profit function. As a result, Tornqvist-Theil index is the

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[1] Because of "zeros problem" we approximated Ln (X^t/X^{t-1}) as $\frac{X_t - X_{t-1}}{(X_t + X_{t-1})/2}$.

appropriate index for a second order differential approximation to any arbitrary non homothetic production technology (Caves, Christensen, and Diewert, 1982).

3. DATA

We consider outputs and inputs measures for both crop and animal sectors. Our most disaggregate measures are province (50) productivity indices. The data set contains information on the prices and quantities of 41 output categories: 32 crop and 9 livestock commodities. The total value generated for crop categories represents 75.5% of the total crop value in 1962 and 71.8% of the total crop value in 1989. For livestock these figures are 62% and 87.6%, respectively. National farm prices are a weighted mean considering regional prices for different varieties and qualities for each crop and livestock commodities.

The input categories that we derived measures for are sector-specific. For the crop sector, the inputs selected in the study were: land, labor, capital services, seeds, fertilizers and manure, animal labor, and energy. For the livestock sector, inputs considered were: animal feed, land, labor, capital services and livestock capital.

Total input indices and TFP indices are measured in stock terms. Land is measured by the crop area. Land input includes both cropland and pasture. These two categories are further divided into irrigated and non irrigated land. To measure the service flow from land, real cash rent series were developed for the four land categories. Rent was estimated as a percentage of the land value (percentage, 10 per cent).

A stock variable is also used to measure labor quantities: number of workers in agriculture. A distinction is made between hired labor (paid workers) and unpaid operators (or family workers). To allocate the actual farm labor series between the crop and livestock sectors we used their relative contribution to total production volume. Data available is not adequate to adjust or correct labor series for quality change.

Two capital categories were considered: expenditures on repair and operation of machinery, and machinery units. The first may be thought as a variable expense, and the second is a measure of quasi-fixed factor capital. The input to production from this quasi-fixed factor is its service flow. No data is available on buildings structures to be included as a quasi-fixed factor. Repair and operation of machinery includes lubricants, tires and expenditures on repairs. The value of machinery service is estimated as to the machinery depreciation plus a fixed percentage (4 per cent) of their current value at replacement cost. This percentage was

used as a proxy for farmers' view of the long-term interest rate to which the marginal product of capital should correspond.

We included as intermediate input measures expenditures on commercial seeds bought by farmers, fertilizers, feed and energy. The Ministry of Agriculture publishes national data on expenditures and quantities for three types of fertilizers: nitrogenous, phosphatic and potash fertilizer. We considered two energy expenditures: oil and electricity. Two types of feed inputs were considered: a) purchased, commercially-prepared feeds, and b) harvested or simple feed. To express nominal series, for machinery, seeds, and energy, in real terms series were divided by several price indexes published by the Ministry of Agriculture.

We included in the input index a 10 percent of livestock total value, as a livestock capital.

The input and output measures are derived largely from official data published in the Ministry for Agriculture's *Anuarios de Estadistica Agraria*. Also other official sources were employed: National Statistics Institute's *Censo Agrario* and *Anuarios de Estadística*. Labor input measures were computed from non official data published by *Banco Bilbao Vizcaya*.

4. RESULTS

As argued in section 2, TFP can be estimated for a multiple-output multiple-input production system by deflating a Diewert-superlative index of aggregate output by a Diewert-superlative index of aggregate input, and a Tornqvist-Theil type was chosen.

Table 1 reports the indices for aggregate input, aggregate output and TFP for the 1962-1989 period which are plotted in Figure 1. On the bottom part annual exponential growth rates are estimated based on fitting a simple logarithmic growth equation[2]. The TFP grew for the most part of the review period, although it shows marked fluctuations due to changes in weather conditions. The growth of TFP, 2.57% per year, is explained by output growth at 2.41% per year plus input reduction at the rate of 0.16% per year.

In Figure 1 it is possible to distinguish three main periods from 1962 to 1989 based on the trends observed in the indices, which are confirmed by the lower part of Table 1[3].

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[2] FAO advises exponential growth rates derived from the regression equations of the form: LN (Y) = a + b TIME. The coefficient of the time trend, b, is the compound growth rate. The exponet of this minus unity (e^b-1) is the annual growth rate.

[3] We include in parenthesis rates of growth for similar periods

Table 1. Tornqvist-Theil Indices for Inputs, Outputs and TFP for Spanish Agriculture			
Year	Input	Output	TFP
1962	1.00998	0.97293	0.96332
1963	1.00666	1.04698	1.40006
1964	0.98336	0.98009	0.99667
1965	0.97883	0.98276	1.00401
1966	0.98964	1.00790	1.01845
1967	0.99658	1.02715	1.03068
1968	0.99329	1.08627	1.09361
1969	1.00656	1.12522	1.11788
1970	1.02321	1.16451	1.13810
1971	1.03007	1.25805	1.22132
1972	1.02959	1.28408	1.24718
1973	1.03960	1.41896	1.36491
1974	1.01640	1.39882	1.37624
1975	1.00074	1.43537	1.43430
1976	1.01562	1.43486	1.41279
1977	1.00736	1.41100	1.40069
1978	1.02007	1.54004	1.50974
1979	0.99854	1.57950	1.58181
1980	0.95108	1.62687	1.71056
1981	0.95004	1.49824	1.57702
1982	0.96474	1.62995	1.67916
1983	0.95977	1.55567	1.62089
1984	0.96811	1.73207	1.78912
1985	0.95490	1.67469	1.75378
1986	0.96444	1.65290	1.71385
1987	0.98284	1.73647	1.76679
1988	0.97738	1.68466	1.72364
1989	0.98765	1.71551	1.73696
Annual Average Growth Rates (%) by Period, 1962-89			
1962-89	-0.16	2.41	2.57
1962-70	0.15	2.00	1.84
(1962-71)	(0.28)	(2.50)	(2.21)
1970-80	-0.53	2.90	3.44
(1971-81)	(-0.75)	(2.13)	(2.90)
1980-89	0.38	1.09	0.38
(1981-89)	(0.40)	(1.40)	(0.99)
1980-85	0.20	1.55	1.34
(1981-85)	(0.14)	(2.94)	(2.80)
1986-89	0.66	0.82	0.15

During 1962-1970, TFP rose steadily and rapidly showing an annual average growth rate of 1.84%. TFP increased even more rapidly from 1970 to 1980, 3.44% per year, but the trend is reversed after 1980, and during 1980-1989 TFP grew at only 0.38% per year. The 1980-1989 period can be divided into two subperiods, pre-EC (1980-1985) and after 1986, when Spain

joined the EC. During the first subperiod TFP growth already decreased compared to the previous decade showing an annual growth rate of 1.34 % per year. But it is after 1985 when productivity growth fell substantially to 0.15%, a very low level.

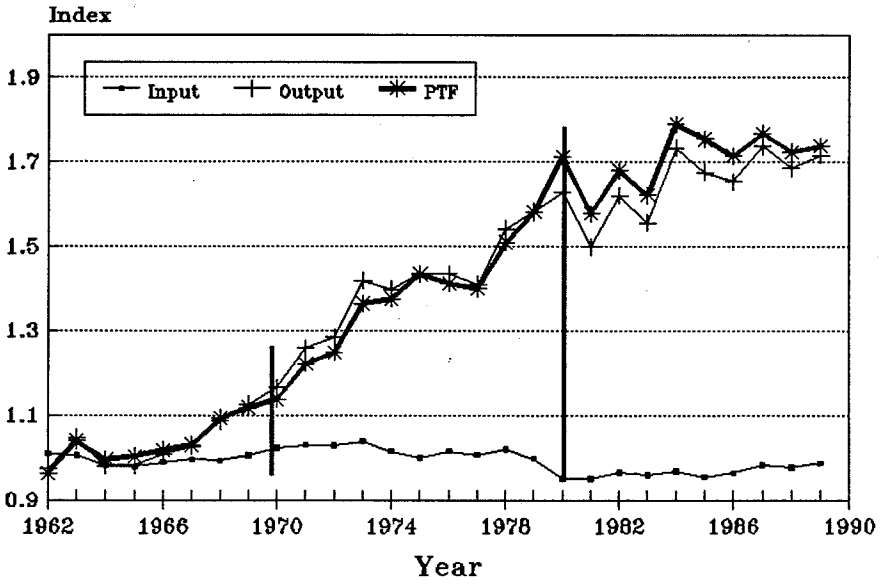

Figure 1. Output, Input and TFP for Spanish Agriculture

The trend observed in TFP must be explained by the behaviour of the output and input indices. The period 1962 to 1970 is characterized by of high production growth (2.00% per year), which is capital intensive. Table 2 and figure 2 show the important increase in capital and intermediate inputs over the period (7.41% and 2.33% per year, respectively). The increase in capital intensity is combined with a decline in labor force (3.18% per year) and a relative small increase in land input (0.10% per year)[4]. In overall terms, production growth is the result of a slight rise in the volume of total inputs, although the increase in the capital/labor ratio is substantial. Productivity kept a pace with production growth, as it is shown in Figure 1.

[4] The estimated trends are less meaningful for inputs whose shares of the total cost are low. Also, it should be kept in mind that average growth rates for individual aggregate input indices weighted by their shares do not equal total input index growth rate.

The rate of output growth increased slightly during 1970-1980 while total input used declined modestly at 0.53% per year (table 1). Through these years rural exodus was maintained producing a reduction in the agricultural labor force of more than 10% per year (table 2 and figure 2). Land remained stable and the rate of capital accumulation, although still positive, decreased significantly to 1.32% per year. It is only in intermediate inputs where rates of growth increased with respect to 1962-1970 levels. In sum, technological change in this subperiod seems to had been directed more towards producing cost savings than to generating output increases[5].

Table 2. Annual Average Growth Rate for Inputs by periods (%)

	Labor*	Land	Capital	Intermediate Inputs**
1962-1989	-10.37	0.39	1.92	2.36
1962-1970	-3.18	0.10	7.41	2.23
(1962-1971)	(-3.16)	(0.47)	(6.92)	(2.21)
1970-1980	-9.17	0.18	1.32	3.03
(1971-1981)	(-10.7)	(0.06)	(0.85)	(2.93)
1980-1989	-22.79	0.24	0.59	2.08
(1981-1989)	(-24.50)	(0.24)	(0.60)	(2.00)
1980-1985	-14.02	0.27	0.19	1.88
(1981-1985)	(-13.57)	(0.29)	(-0.01)	(1.44)
1986-1989	-46.71	0.16	0.54	2.87
Share 1962-1989	31.1	40	5.4	23.5

* Last year for labor index is 1988.
** Include seeds, fertilizers and manure, animal labor, energy and animal feed.

From 1980 to 1989 the output growth slowed considerably (1.09% per year) while total input increased slightly (0.38%). The slow down in output growth was particularly relevant after 1985. The result is an important reduction in productivity growth from previous periods. The relative decline in agricultural labor is very high showing an annual rate of 22.79% per year.

[5] This trend is more apparent if the period 1971-1981 is considered instead of the period 1970-1980.

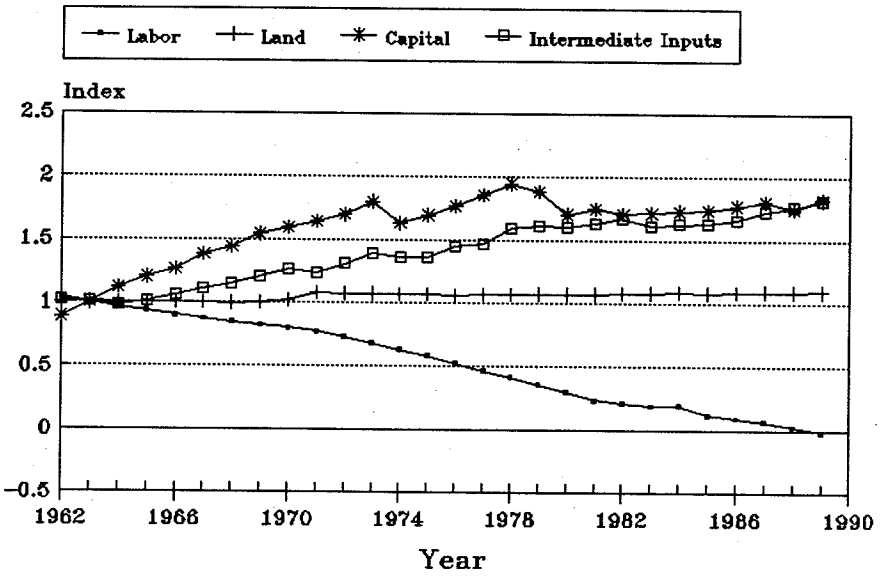

Figure 2. Individual Inputs Trends by Type

On the other hand, land use slightly recovered from the 1970-1980 levels showed rates of growth of 0.24% per year. Both capital and intermediate input grew during this period but a lower rates than in the former period, 0.59% and 2.08% respectively. The resulting annual average growth rate for all inputs was just slightly inferior than the rate of growth of output, which result in stagnation in productivity.

Disaggregation to the crop and livestock sector level can be useful to explain the nature of the changes observed in input, output and TFP. Table 3 reports the annual average growth rate of the indices for inputs, outputs and TFP for both, crop and animal production during the review period, and figures 3 and 4 illustrate these indices. Livestock output grew at 2.67% per year during the entire period while crop output grew at 2.17% per year. The performance of both sector in the three subperiods analyzed is also different. In 1962-70 crop and livestock sector showed different rates of growth, 1.70% and 3.17% per year, respectively. In the next period, 1970-1980, the rate of growth in the crop output index increased substantially to 2.36% per year, whereas livestock output increases still showed a higher rate of growth than crop output, over 3.6% per year. The trend is reversed after 1980, and during 1980-1989 period,

there is a negative rate of growth in livestock output (-0.39% per year) while crop production increased although at a lower rate than in the previous period (1.56% per year).

Table 3. Annual Average Growth Rate for Crop and Livestock Sector, %

Period	Input Crop	Input Livestock	Output Crop	Output Livestock	TFP Crop	TFP Livestock
1962-1989	-0.65	0.41	2.17	2.67	2.85	2.25
1962-1970	0.19	0.42	1.70	3.17	1.50	2.73
(1962-1971)	(0.42)	(0.45)	(2.31)	(3.36)	(1.89)	(2.89)
1970-1980	-1.29	0.53	2.36	3.69	3.70	3.15
(1971-1981)	(-1.82)	(0.74)	(1.32)	(3.43)	(3.20)	(0.37)
1980-1989	0.6	-0.16	1.56	-0.39	1.24	-0.22
(1981-1989)	(0.32)	(-0.67)	(2.12)	(-0.61)	(1.51)	(0.06)
1980-1985	-0.31	0.69	2.06	0.56	2.37	-0.13
(1981-1985)	(0.37)	(-0.66)	(4.43)	(0.32)	(4.04)	(0.99)
1986-1989	0.25	0.34	1.07	-1.06	0.82	-1.40

Input path also differs in the two sectors. While the rate of growth of total input in the crop sector was negative when we consider the complete reference period (-0.65% per year), the livestock sector slightly intensified factor quantities at a rate of 0.41% per year. The reduction in crop factors used took place during the 70's (-1.29% per year, see also figure 3). On the other hand, livestock sector input use still increased until 1980, showing a negative trend in the following years.

As a result of these different trends of aggregate input and output, TFP for crop sector was higher than TFP for livestock sector (2.85% > 2.25%) during the global period considered 1962-89. Only during the period 1962-1970 the livestock sector showed a better productivity performance (2.73 %) than the crop sector (1.50%). In the 1970-80 period TFP growth were over 3% in both sectors. During these years Spanish agricultural sector showed its best performance. However, the situation worsened considerably in the period 1980-89 in which the lowest growth rates for both crop 1.24% and livestock 1.00% are observed.

There are several possible explanations of the reverse trend in TFP shown in the 1980-1989 period. First of all, persistent drought has affected agricultural output throughout the period, specially in years 1981, 1983, 1985 and 1986. In addition, the effect of output prices and production restrictions in livestock products after Spain accession to the EC in 1986 has also probably contributed to the recent decline in output growth. Lastly, it seems plausible that the

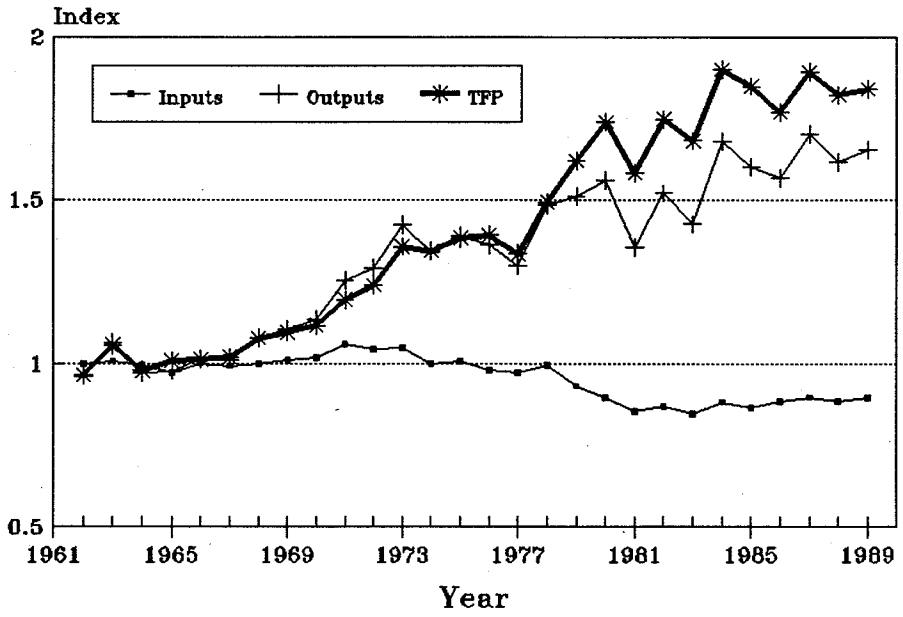

Figure 3. Output, Input and TFP for Spanish Crop Sector

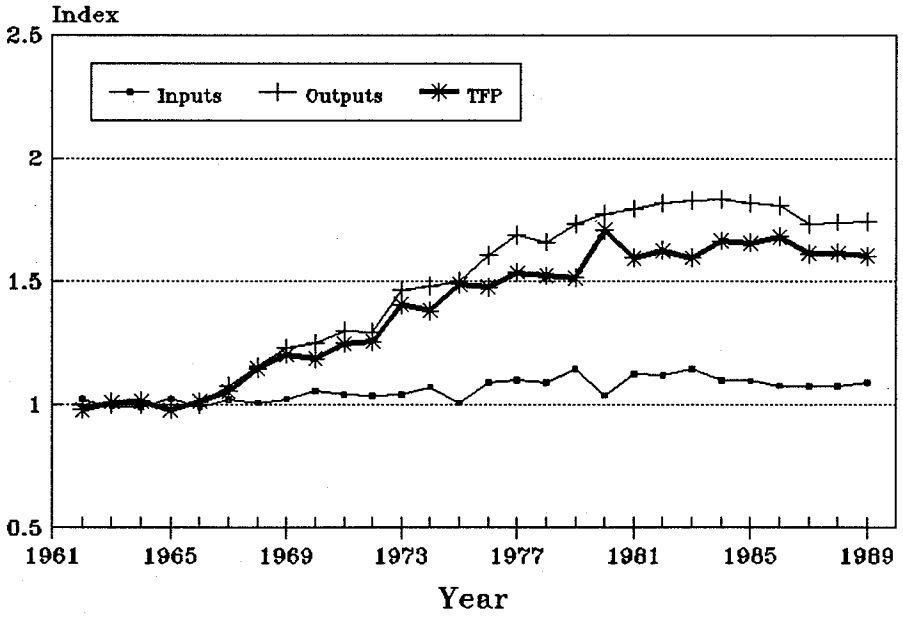

Figure 4. Output, Input and TFP for Spanish Livestock Sector

model of technical change followed since early 1960s, biased towards foreign technology and input intensification, could be also responsible for the stagnation in production observed.

Table 4 reports some studies which use index numbers to measure TFP in other EC countries. Although one must be careful when drawing conclusions about different TFP measures[6], to asses the performance of Spanish agriculture it is instructive to compare TFP growth in other EC countries with TFP growth in Spain.

Table 4. TFP International comparisons

Study	Country	Period	Index Type	Annual Growth Rate
Bureau et al, 1988	Germany France Netherland Belgium Luxemburg Irland Italy Denmark Greece	1967-87	Fisher	1.29 2.38 2.17 1.51 3.17 2.13 1.55 2.54 2.18 1.49
Thirtle & Bottomley, 1992	UK	1967-90	Tornqvist	1.88
Rutten, H, 1992	Netherland	1949-89	Tornqvist	3.01
Mergos, 1993	Greece	1961-90	Tornqvist	0.7
Boyle, 1987	Irland	1960-82	Fisher	1.07

To reduce comparison problems only studies using similar periods as ours and aggregating quantities by Tornqvist and Fisher aggregator have been considered, as shown in table 4. In practise, both Fisher-Ideal and Tonqvist-Theil give very similar results (Bureau et al. 1988 p.151).

Spanish estimated trend for TFP growth is in line with those of other Mediterranean countries like France and Italy, as reported by Bureau et al.(1988). It is also interesting to point out that Mergos (1993) study for Greece reports an important decline in TFP growth in this country after joining EC, as it has been the situation observed in Spain.

[6] Due to methodological differences, number of inputs and outputs included in the analysis, quality adjustment in variables, and reference periods and base year considered.

5. CONCLUSIONS

This paper measures TFP in Spanish agricultural sector from 1962 to 1989. Our calculations reveal that the rate of productivity growth has been high up to 1980, but has dropped considerably since then to 0.38% per year. The stagnation of productivity in the 1980's is observed in both the livestock and crop sector, although the later performed better in term of productivity growth during the rest of the reference period. In general we can say that Spanish agriculture has performed well in terms of productivity growth through the period considered when compared with other EC countries.

The sharp decline in productivity growth in the 1980s can be attributed to unfavourable weather conditions, lower output prices and quantities restrictions for livestock products after joining the EC, and also to the limitations of a model of technical change initiated in the early 1960s based on input intensification and imports of foreign technology. The latter could have important implications regarding agricultural research policy in the country. However, to further confirm these hypothesis it would be necessary to relate the TFP measures obtained in this study to explanatory variables such as research (national and international), extension, schooling and infrastructure.

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