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ECONOMETRIC MODELS OF AGRICULTURE IN OECD COUNTRIES: PRODUCTION, INCOME, AND AGRARIAN EMPLOYMENT IN SPAIN, FRANCE, JAPAN, AND THE USA, 1965-99.

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Abstract
We present a general view of agricultural employment in four OECD countries: Spain, France, Japan and the USA during the period 1900-1999 and we analyse the effects of the technological transformation this sector underwent during the period 1965-99, by means of an econometric model for agrarian employment and real valued added. A pooled regression is selected after testing the homogeneity of parameters in the four countries. The conclusions point to the important diminution in relative prices of agriculture as the main explanatory variable which accounts both for employment decrease and stagnation, or decline, in agricultural real income, in spite of high increases in real production. The study of this is important as many developing countries are now facing such a socio-economic transformation. There is a need for a change in order to foster analyses of income, prices and other important variables related with the quality of life both of farmers and consumers.

JEL Classification: C51, N50, O13, O51, O52, O57

1.- Introduction

During the 20th century Agriculture experienced an important increase in production and productivity in relation with cultivated land all over the world, especially in countries with high levels of technology and physical capital by inhabitant.

Before the 20th century, increases in agrarian production usually only occurred as a result of the size of farming land as Ruttan(2002) points out, and he adds that a change has occurred from an Agriculture natural resource-based system to a science-based one.

The study of this transformation is important as many developing countries are now facing the effects of such a socio-economic transformation. This transformation will be impressive in countries of bigger size, such as China and India, as they will experience an important socio-economic change with thousands of millions of workers moving from agrarian activities to non-agrarian employment, which in many cases also implies migration from rural villages to towns and cities.

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The costs are generally associated with important emigration movements from rural areas to villages and cities with higher levels of non-agrarian income and employment, and the opportunities are related with the possibility of a general improvement in the levels of real income per head, both for agrarian labourers and for those that have moved to non-agrarian activities.

Many regions in industrialised countries experienced this transformation many decades ago, while others have only recently reached levels of non-agrarian employment which are higher than agrarian.

The challenges for the biggest developing countries, such as China and India, or large areas of Latin America and Africa, depend heavily on good internal economic policies and international co-operation, in order to make this agrarian transformation with low costs and substantial benefits for their inhabitants.

So it is, in our view, of interest to analyse the evolution of countries that have previously experienced this transformation to learn some lessons that could help develop favourable policies.

In section 2 we present the evolution of employment, real production, relative prices and income of this sector in some European Union countries, the USA and Japan. Besides Agriculture, this sector also includes Forestry and Fishing, because the international statistics of Value-Added and Employment are expressed in these terms.

There we will see that the level of agrarian employment fell during the 20th century in all of the countries analysed, and in spite of high increases in production, real income shows stagnation and even decline in some periods.

In comparison with another branches of the economy, Agriculture prices showed a more outstanding trend towards a decrease in real terms during the second half of the 20th century. So the price index of Agriculture generally evolved much less than the general price index of private consumption.

We feel it necessary to examine this feature which explains stagnation or decrease in agricultural real income, a general reduction in agrarian employment and very significant emigration movements from farming and fishing to another sectors.

With this goal in mind we have developed the econometric models presented in section 3, where we analyse the relationship between several variables of interest for the design of adequate development policies for countries that are starting to undergo agricultural transformation.

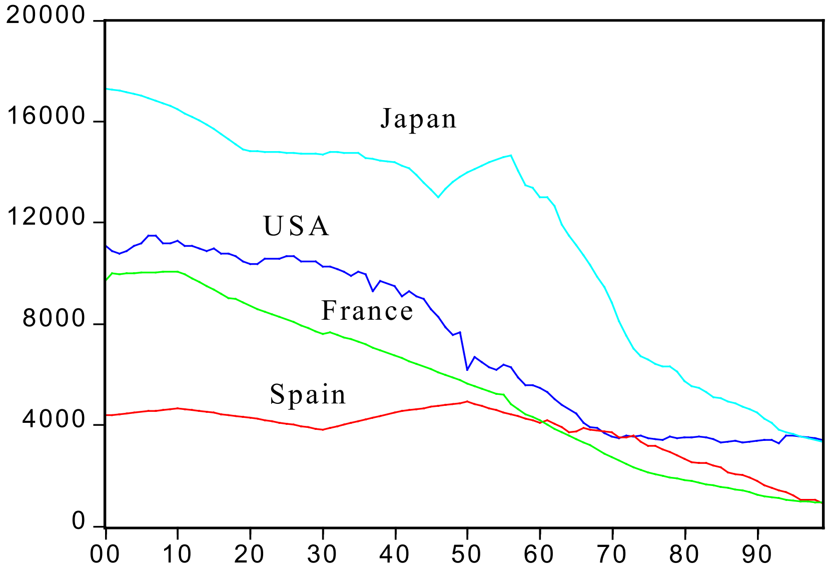
After analysing the evolution of Agriculture in some OECD countries during the period 1900-99 we present in section 3 a short summary of Agriculture modelling approaches and in sections 4 and 5 we present our models for employment and real value-added. Finally in section 6 we present the main conclusions.

2.- Evolution of Agrarian Employment, Production, Income and Prices, 1900-1999

Graph 1 shows levels of agrarian employment in the European Union (EU), the United States of America (USA), and Japan during the 20th century. For the first half of the century our estimations are based on historical statistics cited in Guisan et al(2001). Data for the second half is based on statistics from the OECD and some complementary sources. Agriculture includes not only farming but also fishing and forestry.

The estimations for European Union employment during the years of the first and second world wars only represent a provisional estimation as we could not obtain exact information concerning the real levels in those years. In spite of the limitations due to the unavailability of some data, we think that the figures represent adequately the general trends. The same happens with the data corresponding to the Spanish civil war of 1936-39.

Graph 1. Evolution of Agrarian Employment, 1900-1999
(thousands of workers)

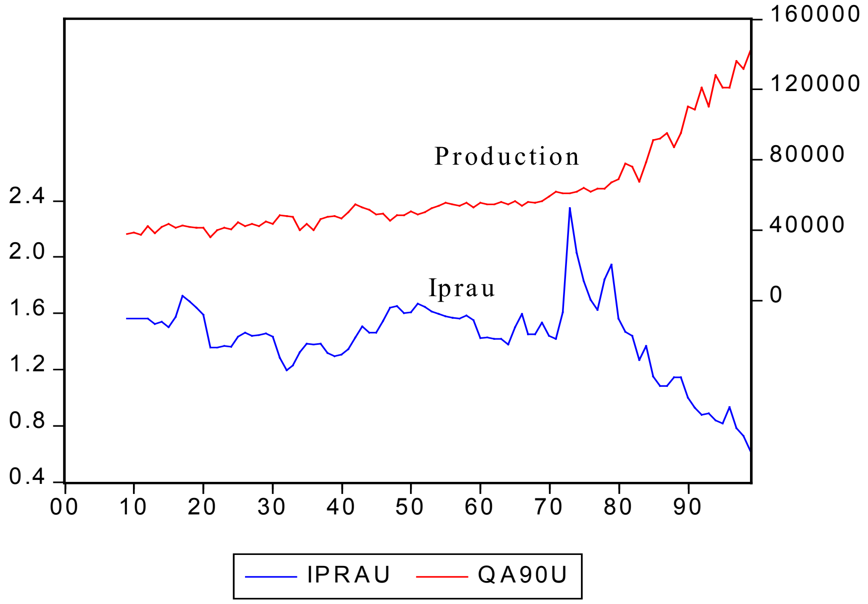


Graph 2 presents the evolution of real production and the relative price index of Agriculture in the USA.

Real production is measured by the ratio between value-added at current prices and the index of prices of agrarian Value-Added, expressed in millions of dollars at 1990 prices.

IPRAU is measured by the ratio between the index of prices of Value-Added of Agriculture and the index of prices of Private Consumption, both equal to 1 in 1990.

Graph 2. Production and Index of Price Ratio of Agriculture in the USA 1900-1999
(millions of dollars at 1990 prices and ratio between IPA and IPC)



The technological revolution in Agriculture, and other circumstances such as the expansion of non-agrarian income and employment and the reduction in relative prices of agrarian value-added, together with the corresponding negative impact on agrarian income at constant prices, explain the significant reduction in employment in Agriculture during the 20th century in all industrialised countries.

With regards the evolution of relative prices we can see that the main changes in IPRAU happened during the decade 1970-79 with a high increase followed by a recovery of previous levels and a negative trend after 1980. This negative trend occurred at the same time that real production experienced a rapid expansion, and both circumstances are very much related.

After this general look at evolution of Agriculture in the 20th century, we concentrate our commentary on the second half, particularly in the period 1964-99, for which there is more comparative data thanks to OECD National Accounts Statistics and other international sources.

Graphs 3 to 6 present the evolution of agrarian production, income and prices in the USA, France, Spain and Japan. France and Spain represent two different types of EU countries, the former being representative of highly industrialised countries while the latter represents a more moderate level.

Income and Production are measured in millions of dollars at 1990 prices and purchasing power parities, PPPs, and their values are on the right axis of the graphs. Income represents the acquisitive power of Gross Domestic Product in Agriculture, and it is measured by the ratio between Gdp of Agriculture at current prices and the index of prices of private consumption of each country. Production represents the production capacity and it is measured by the ratio between Gdp of Agriculture at current prices, and the Agriculture implicit price index of each country.

Both variables are expressed in millions of dollars at 1990 prices and Purchasing Power Parities, PPPs. Gdp of Agriculture includes farming, fishing and forestry and is measured at market prices, and thus it does not take account of the effect of agrarian net subsidies.

The relative price of Agriculture is the ratio between the Agriculture implicit price index and the price index of private consumption of each country, and it is represented on the left axis of the graphs.

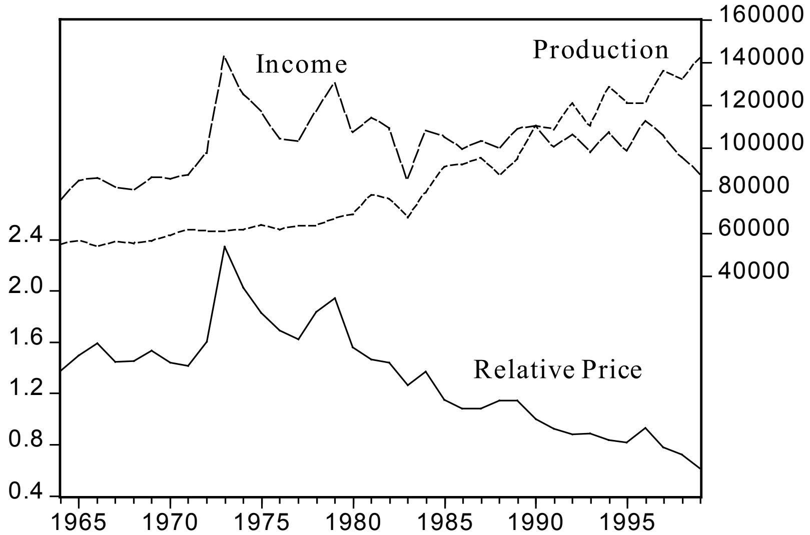
In graph 3 we can see that the USA experienced an exceptional increase in the relative price of Agriculture during the period 1971-73, but a general declining trend afterwards.

The increase in the other countries during that period was considerably less, and all of them also show the general trend towards the diminution of this variable. The conclusion is that agrarian prices lost half or more of their position relative to the general price index of consumption during the period 1964-99.

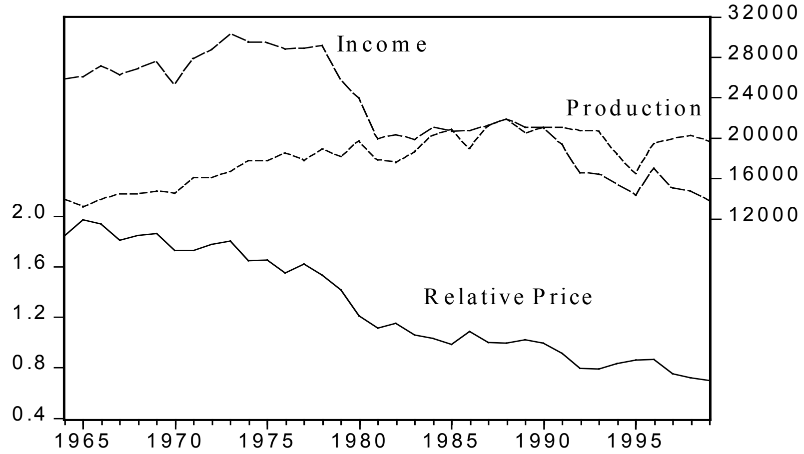
This relative depreciation of agrarian products reduced the real total income from agricultural activities in spite of the increase in production in many countries, as was the case during the period 1964-99 for Spain, which experienced an approximate 50% decrease in real income, and France an approximate 25%, despite significant increases in real production.

In the USA the real total income from agricultural activities was very similar at the beginning and at the end of that period although real production increased more than 100%. In Japan, income experienced a clear decrease while the levels of real production of 1999 are very similar to those of 1964.

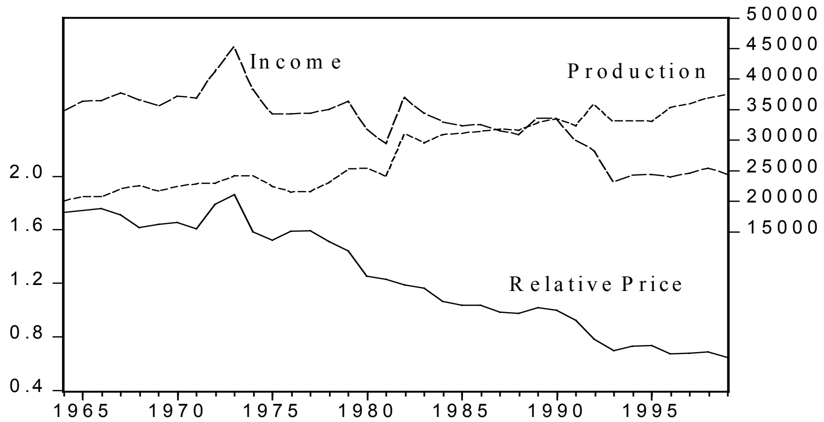
Graph 3.- Income, Production and Relative Price of Agriculture in USA
(millions of $US at 1990 prices and PPPs, and index of prices)



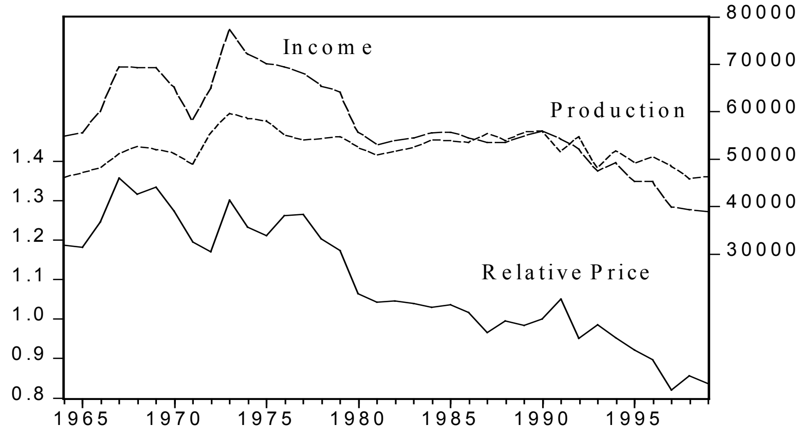
Graph 4.- Income, Production and Relative Price of Agriculture in Spain
(millions of $US at 1990 prices and PPPs, and index of prices)



Graph 5.- Income, Production and Relative Price of Agriculture in France
(millions of dollars at 1990 prices and PPPs, and index or prices)



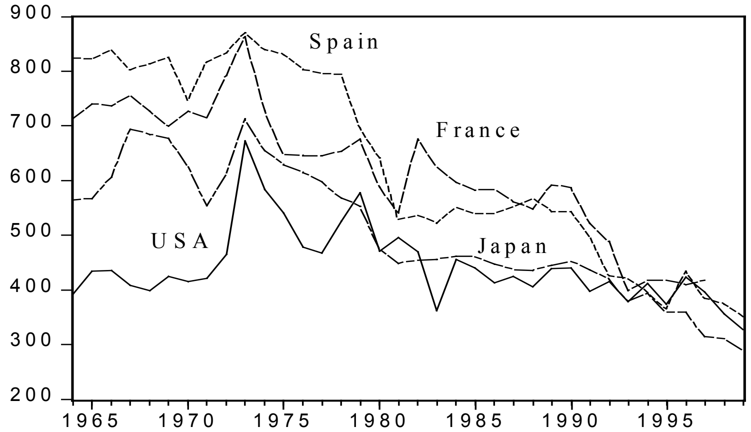
Graph 6.- Income, Production and Relative Price of Agriculture in Japan
(millions of dollars at 1990 prices and PPPs, and index of prices)



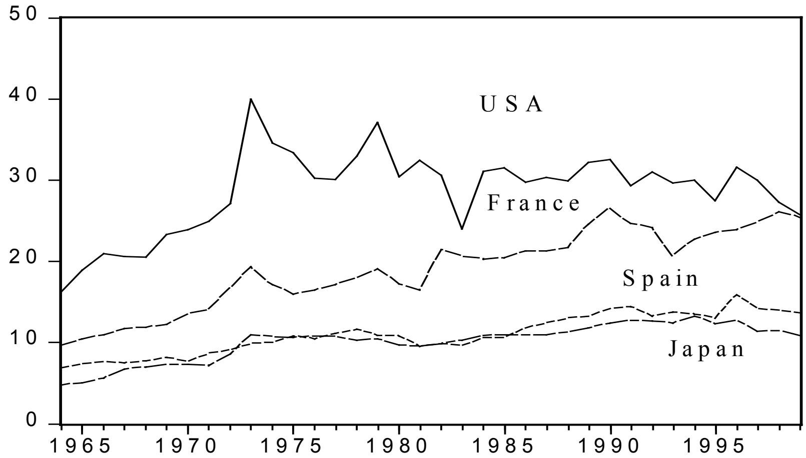
The real Value-Added by inhabitant, from the income approach has usually decreased during this period, although the real income by worker has generally increased as we can see in graphs 7 and 8.

In graph 8 we can see a convergence between the levels of real income by worker in the cases of France and the USA, as well as a very similar evolution, at a much lower level, between Spain and Japan.

Graph 7. Real Value-Added in Agriculture, by inhabitant, income approach (dollars US at 1990 prices and PPPs)



Graph 8. Real Value-Added by worker, income approach (thousands of $US at 1990 prices and PPPs)



In our view farming subsidies are very appropriate in some cases, and this arises from international differences in productivity. In the cases of Spain and Japan it seems clear that these countries can only converge their levels of real income per worker with the USA and France through subsidies policies focused mainly on increasing the real income of agrarian workers. In this regard we agree with some criticisms to EU agrarian policy, such as those posed by Colino et al(2001) because that policy has usually focused excessively on subsidising high crop quantities instead of helping to maintain agrarian employment and to increase real income per worker at the same time.

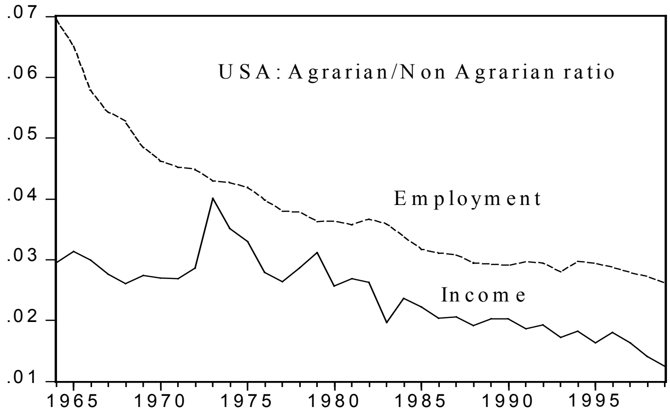
Public opinion polls have revealed a high degree of interest in the European Union subsidising the quality of production and improving real income by agrarian workers but EU agrarian policies designed by EU bureaucracy in our opinion do not take these aims into account to the desired degree.

We think that agrarian subsidies should be maintained to some degree, in order to avoid an excessive decrease of employment and loss of food quality. However, we also think a policy balanced between protection of own production and natural environment and the openness to external goods would be beneficial.

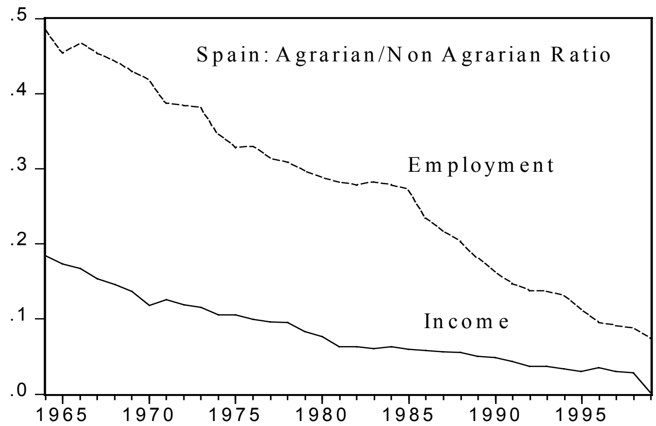
Before presenting our econometric models of agriculture we include graphs 9 to 12 in order to see the loss of relative importance that agrarian activities have experienced in comparison with non-agrarian ones.

These graphs show a diminution of the agrarian/non-agrarian ratio, as well as a trend towards more convergence between the employment ratio and the real income ratio.

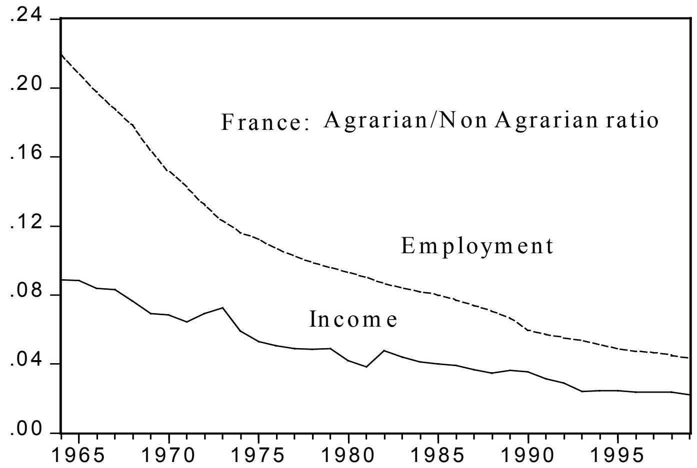
Graph 9. Ratio of Agrarian/non Agrarian activities in the USA



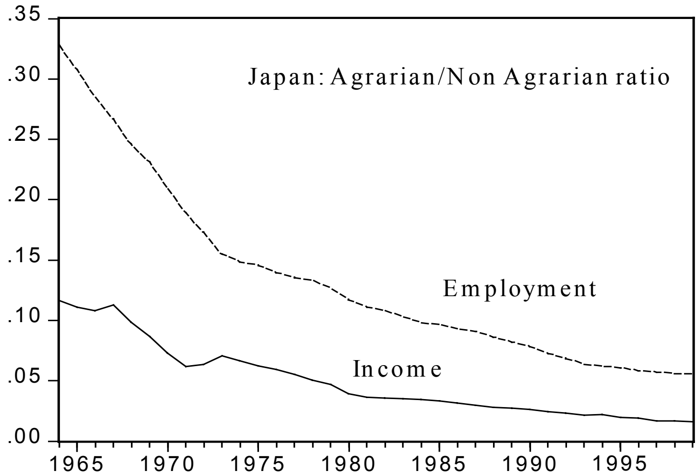
Graph 10. Ratio of Agrarian/non Agrarian activities in Spain



Graph 11. Ratio of Agrarian/non Agrarian activities in France



Graph 12. Ratio of Agrarian/non Agrarian activities in Japan



The fact that agrarian income value is less than 5% of non-agrarian income does not imply that the activities included in the agrarian sector are not important for economic development. As we have previously mentioned there are several positive effects of Agriculture production on other sectors growth, as those estimated by Guisan, Aguayo and Exposito(2001).

The loss of relative weight in total GDP and Employment is due to the increasing weight of other activities in industry, building and services, but farming, forestry and fishing continue to be important economic activities as they provide other sectors with important raw materials and intermediate inputs which are necessary for their growth.

We must realise that Agriculture impact on other sectors is important, because many activities in industry and services depend on agrarian production and/or imports, an so the total impact on the economy should be evaluated taking into account these indirect and positive effects through inter-sector relations.

In the next section we make reference to some econometric approaches related to Agriculture modelling and after this general view we present the estimation of our models of employment and production in Agriculture in Spain, France, Japan and the USA.

3.- Econometric models of Agriculture

Perhaps the highest concentration of Agrarian quantitative studies has occurred in productivity studies, especially in the UK and the USA. In this section we make an analysis of some of the main quantitative and econometric approaches in the study of Agriculture over recent decades.

First, we analyse the studies of Total Factor Productivity, and besides this the role of Agriculture in economic growth through macroeconometric studies.

Total Factor Productivity Studies

Huffman and Evanson(1992) report that the first studies of total productivity of Agriculture in the USA were started in 1948, and Thirtle and Bottomley(1992) consider that similar studies for the UK were made in 1949.

One of the most renowned studies of agricultural productivity was made by Ball(1985), by means of Tornqvist-Theil productivity indices for different categories of output: animal production, milk products, cereals and fodder, other agriculture products, vegetables and melons, fresh fruit and dry fruit.

Among the inputs he analyses:

1) labour, with the novelty of considering qualitative features (sex, 8 groups for age, 4 groups for educational level, 2 groups for kind of employment and 10 groups for kind of activity).

2) Stock of capital, using the model of Jorgenson(1963) of perpetual inventory:

$$A_{it} = I_{it} + (1- \delta_i) A_{i,t-1}$$

where A is the stock of capital, I is investment and δ is the rate of depreciation.

That study considers 12 categories of assets, allowing for a detailed analysis of the different factors on the productivity index.

Ball built Törnqvist-Their indices for these variables and applied the following index of total productivity:

$$Ln(TFP_t / TFP_{t-1}) = ½ \ \Sigma (R_{it} / R_{i,t-1}).ln(Y_{it}/Y_{i,t-1}) – ½ \Sigma (S_{jt}/S_{j,t-1}). Ln(X_{jt}/X_{j,t-1})$$

where Y_i are indices of output, X_j are indices of inputs, R_i is the share of output in income and S_j the share of input in cost.

Ball estimated the average yearly rate of growth in productivity as 1.75%, for the USA in the period 1948-79, a very similar figure to the rate of 1.7% estimated by the U.S. Department of Agriculture, USDA.

Evenson et al.(1987) estimated the index of total productivity at regional level for the USA during the period 1950-82, and they also compare their results with the estimations elaborated by the USDA.

Thirtle and Bottomley(1992) also utilised the Törnqvist-Thei index for calculating the total productivity index for the UK during the period 1967-90. They consider five categories of output and nine kinds of input, including interest rates as opportunity cost for agricultural capital stock, considering the 3% suggested by the USDA. They found a first stage of increasing productivity and a descending trend after 1985, and they consider that the main cause of this decrease was due to the lowering of agriculture prices as a consequence of the European Common Agrarian Policy, CAP.

Another study is that of Fernandez-Cornejo and Shumway(1997) for Mexico during the period 1960-90. They consider 52 categories of output and 7 categories of inputs. They estimate an average yearly growth of total productivity of 1.3%, with 2.5% for the last part of that period, a figure which is greater than the estimated value for the USA which was 2.1%.

These authors tried to measure the impact of research on productivity by means of a cointegration analysis of the linear relation between the log of Total Factor Productivity, TPF and the logs of Research Expenditure and International Transfer of Agriculture Research. They estimate that an increase of 1% in direct expenditure on agricultural research increases TPF by 0.13%, and that the transfer from the USA implies an increase of 1.1% in Mexico when the USA research expenditure increases by 1%.

In Spain, Fernandez, Herruzo and Evenson(1995) analyse the TPF of agriculture in Spain at regional level during the period 1962-89. They utilise the discrete approximation of Divisia to the Törnqvist-Theil index.

The conclusions of several studies of total factor productivity are very often contradictory. So Pardey and Craig(1989) conclude that there is a causal relation between public expenditure on agricultural R&D and productivity in the USA, and a similar result is achieved by Fernandez-Cornejo and Shumway(1997) for Mexico, while Hallam(1990) get the opposite result for British agriculture using a co-integration approach.

As we have seen in the graphs in section 2, real production measured by the quotient between Value-Added at current prices and its own price index, generally shows a growing trend, while an important input such as labour shows a declining trend. Although there are increasing amounts of another inputs such as stock of capital and research expenditure, it seems that all in all the increases in total factor productivity are generally positive, but the same does not apply if we analyse total factor income, instead of total factor productivity, with real income by means of Valued-Added at current prices divided by the general index of consumption.

Some contradictions in the results of several studies concerning causal relations could be due to the way real output is measured, although they could also be due to the uncertain results that the cointegration approach often presents, as analysed in Guisan(2001).

In section 5 we will see that the impact of the negative evolution of real prices in agriculture shows a positive impact on real production and a negative impact on real income.

The role of Agriculture in macro-econometric models

Generally the role of Agriculture in macro-econometric models is related with foreign trade equations, as the increase in Real Value-Added of Agriculture is considered to reduce the demand for imports of this group of goods, and to increase, in some countries, the capacity for exports. In this regard Agriculture is an explanatory variable, usually considered as exogenous, which has a positive role in demand side terms, as it contributes to increase exports and reduce imports.

Very few macro-econometric models analyse the impact of Agriculture, and other raw materials producers such as Mining, in supply side terms through inter-sector relations with non-agrarian sectors even though this perspective is also important.

In Guisan, Aguayo and Exposito(2001), using a cross-country sample of 132 countries we have found that, on average, an increase of one dollar in real Value-Added of Agriculture or Industry directly causes an increase of 0.81 in real Value-Added of Services, and a higher impact if we consider a dynamic approach. Other studies also offer important evidence of the significance Agriculture has in economic development.

Agriculture, including farming and fishing, is also very much related with food consumption, and econometric models of consumption expenditure show that supply has an important impact on food demand, not only at national but even at regional level. The type of goods demanded are very much related to the food culture which in many countries is influenced by supply. So we find that the demand for fish, milk and many other products is usually higher in countries and regions that produce them, compared with other areas, although there are another factors such as family income and market distribution which are also important in this regard.

Agrarian activities have a positive influence both from demand side and supply side in the evolution of many activities in industry, building and services.

4.- Employment equation

The important diminution of agrarian employment in OECD countries as a consequence of technological transformation during the 20^{th} century is a challenging issue for many less developed countries which will have to face this socio-economic transformation over the first few decades of 21^{st} century.

The model we present in this section shows that it is very important to increase employment and income in non-agrarian sectors in order to avoid poverty and unemployment in agrarian activities, because redundant workers in Agriculture would then be able to find jobs with equal or better remuneration in other activities.

Equation 1 presents the estimated relation between employment in Agriculture (LA?), measured by number of labourers in the sector, and the following explanatory variables:

RIA?PP = Real income in Agriculture measured by real Valued-Added with an income approach. That is to say by means of the ratio between Value-Added in Agriculture at current prices and the general price index of Private Consumption. This variable is expressed in millions of dollars at 1990 prices and Purchasing Power Parities, PPPs.

LNA? = Non agrarian employment measured in number of people

RINA? PP = Real income in non-agrarian sectors, measured by the ratio between non-agrarian Value-Added at current prices and the general price index of Private Consumption, expressed in millions of dollars at 1990 prices and PPPs.

TI is time, TI=1 in 1961, TI= 7 …., 39 in the period 1967 99.

D(X) is the first differences of a variable X, while the question mark, ?, is the country identifier, ? = U, E, F, J, where U represents the USA, E is Spain, F is France and J is Japan.

The real income corresponds to the acquisitive power of Value-Added at market prices and thus it does not take account of the effect of agrarian net subsidies, which we will try to include in future studies if comparative data for different countries is available.

The selected equation was estimated by means of a sample of 136 observations corresponding to a pool of data from the USA, Spain, France and Japan, in 1965-99.

Equation 1. GLS estimation of Agrarian Employment

Dependent Variable: LA?
Method: Pooled Least Squares
Sample(adjusted): 1965 1999
Total panel (balanced) observations: 136
Convergence achieved after 16 iterations
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RIA?PP)	2.317998	1.048745	2.210259	0.0289
D(LNA?)	-0.017894	0.009642	-1.855898	0.0658
D(RINA?PP)	-0.029342	0.004199	-6.987160	0.0000
LA?(-1)	0.928305	0.020195	45.96716	0.0000
U--TI	3174.181	908.0588	3.495568	0.0007
E--TI	1065.031	678.1165	1.570572	0.1188
F--TI	688.9342	367.1518	1.876429	0.0629
J--TI	2414.630	1247.635	1.935365	0.0552
U--AR(1)	-0.133473	0.186628	-0.715182	0.4758
E--AR(1)	0.606245	0.173689	3.490401	0.0007
F--AR(1)	0.771629	0.138344	5.577620	0.0000
J--AR(1)	0.653838	0.134948	4.845125	0.0000

R-squared	0.998416	Mean dependent var	3433113.
Adjusted R-squared	0.998276	S.D. dependent var	1950886.
S.E. of regression	81006.33	Sum squared resid	8.14E+11
Log likelihood	-1723.805	F-statistic	7106.872
Durbin-Watson stat	2.058661	Prob(F-statistic)	0.000000

The method of estimation was generalised least squares, accounting for autocorrelation, and including White heteroskedasticity consistent standard errors estimators.

The functional form of equation 1 is a mix of relation in levels for LA? and its lagged value, and first differences for the exogenous variables. The symbol ? is used by the program E-views to represent the sub-index of each country in pooling regressions, and letter D before the parenthesis indicates first difference.

This type of equation does not usually need an intercept, nor a common or fixed effects model, and performs very well, with levels of goodness of fit generally as good as the error correction model.

The explanatory variables have significant coefficients in almost all cases with a significance level lower than 5%, and signs of the coefficients as expected: positive and near unity for LA?, positive for D(RIA?) and negative for D(LNA?) and D(RINA?).

This means that increases or decreases in real income of Agriculture imply a change of the same type/sign in agrarian employment, and the opportunities of gaining employment and income in non-agrarian sectors contribute to the abandonment of agricultural employment.

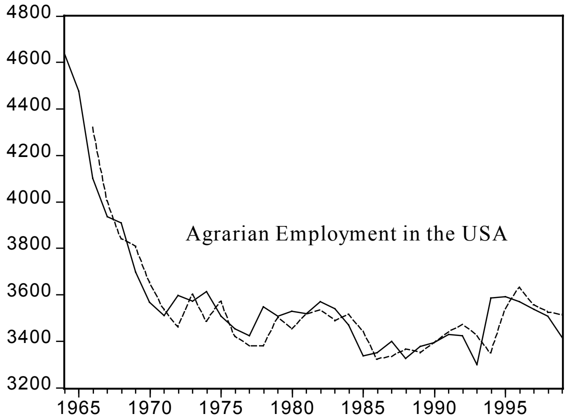
The goodness of fit, in equation 1, is very high with the coefficient of determination, $R^2 = 0.9984$, near unity, and a percentage of only 2.36% for the relation between S.E. and the mean of the dependent variable.

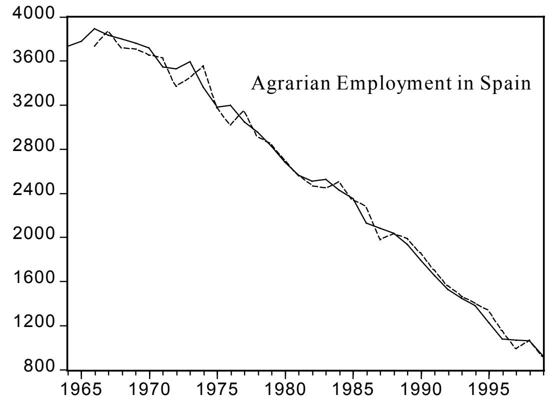
There is positive autocorrelation in the cases of Spain, France and Japan, which could be due to the effect of some omitted variables, for example agrarian subsidies.

Besides the results of the estimated equation we present the graphs of actual/fitted agrarian employment and the residuals graphs.

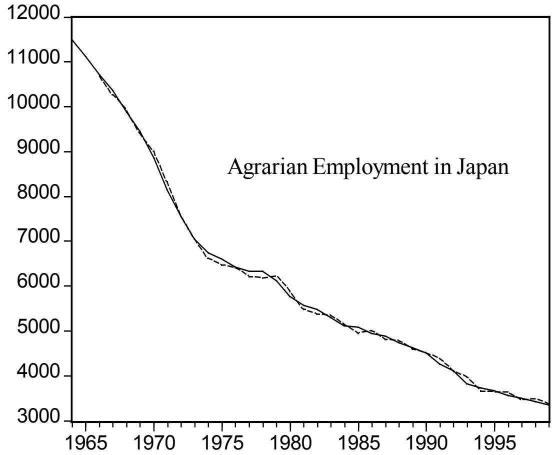
In graphs 13 to 16 we observe a trend towards stabilisation of agrarian employment at the end of the century, after significant decreases during the one hundred year period. Actual and fitted values are very alike because of the high degree of goodness of fit, and also the model explains the evolution of this variable adequately.

Graphs 13 to 16. Actual and fitted values of Agrarian Employment (in thousands)

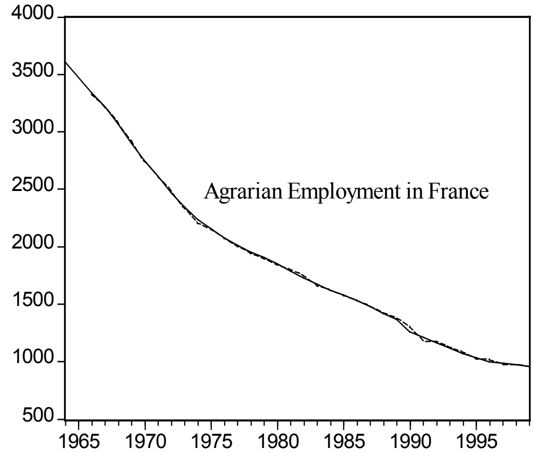




Graph 13



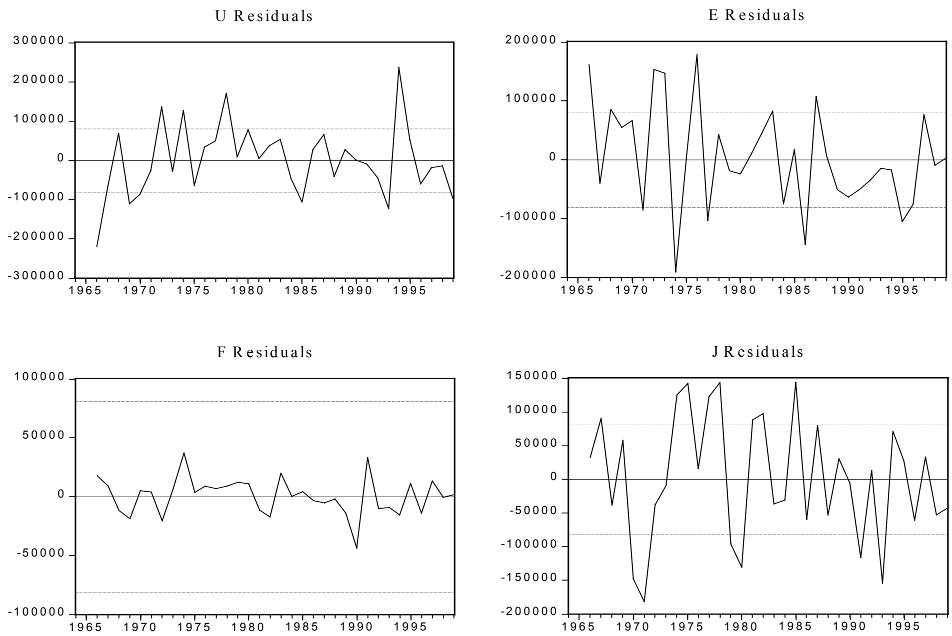
Graph 14



Graph 15

Graph 16

Graphs17, 18, 19 and 20. Residuals of equation 1, for agrarian employment.



The residuals are very low in percentage terms, and so the percentage of Standard Error, S.E. on the Mean of dependent variable is only slightly higher than 2%.

The least squares estimations have shown some small differences between countries, but these differences disappear in the generalised least squares estimation with a different coefficient of TI for each country.

The main variables of equations 1 to 5 are presented, for the years 1965, 1975, 1985, 1995 and 1999, in table 1, where QA means real production measured by real Value-Added according to the production approach, RIA is the Real Income of Agriculture measured by Value-Added according to an income approach, LA is the number of labourers in thousands, IPRA is the ratio between IPA, index of prices of Value-Added of Agriculture, and IPC90, the index of Prices of Private Consumption, and QNA is non-agrarian production, measured by the difference between GDP at 1990 prices and PPPs and QA.

Table 1. Evolution of real production, real income, employment and prices (millions of dollars at 1990 PPPs, thousands of workers, and prices indices)

Country	QNA	QA	RIA	LA	IPA	IPC90	IPRA
USA 1965	2732838	54745	75539	4632	0.356	0.258	1.3798
USA 1975	3607619	63881	116965	3507	0.785	0.429	1.8298
USA 1985	4754592	91307	105140	3338	0.941	0.817	1.1518
USA 1995	6038000	120800	98524	3592	0.940	1.152	0.8160
USA 1999	6257582	142005	87897	3416	0.761	1.229	0.6192
Spain 1965	176967	13216	26108	3586	0.152	0.077	1.9740
Spain 1975	292636	17818	29495	2745	0.293	0.177	1.6554
Spain 1985	344995	20948	20735	1950	0.718	0.725	0.9903
Spain 1995	470720	16567	14387	1107	1.140	1.313	0.8682
Spain 1999	541428	19699	13853	1015	1.024	1.456	0.7033
France 1965	428501	20851	44197	3473	0.285	0.163	1.7485
France 1975	663467	22467	41648	2156	0.493	0.323	1.5263
France 1985	821130	31189	39298	1582	0.884	0.852	1.0376
France 1995	1009429	33098	29698	1039	0.832	1.125	0.7396
France 1999	1108295	37544	29624	959	0.764	1.175	0.6500
Japan 1965	510419	47038	55608	11130	0.325	0.275	1.1820
Japan 1975	1144556	57951	70189	6610	0.719	0.594	1.2104
Japan 1985	1705164	53774	55723	5090	0.974	0.940	1.0362
Japan 1995	2319802	49185	45301	3670	0.975	1.058	0.9216
Japan 1999	2426300	46342	38806	3350	0.896	1.071	0.8366

Source: OECD Statistics and elaboration by Guisan(2003).

This table shows that the increases in real production of Agriculture were much higher than the increase in real income. So in the period 1965-99 real production in the USA changed from 54575 to 142005, implying an increase of 160% while real income only changed from 75539 to 87897 implying an increase of only 16%.

In Spain the change in real production was 49% while real income only experienced a decrease of 47%. In France the increase in real production was 80% and the decrease on real income was 33%. Finally in Japan real production almost experienced stagnation, with a minor decrease of 1.5% while real income decreased by 30%.

3.- Production equation

Equation 2 explains Agriculture production, QA, from supply side, where the logarithm of QA, LQA, is expressed by means of a mixed dynamic equation, where the explanatory variables are its own lagged value and the first differences of the lagged values of the natural logarithms of IPRA, QA and QNA. The symbol D(LX) means first difference of the natural log of variable X.

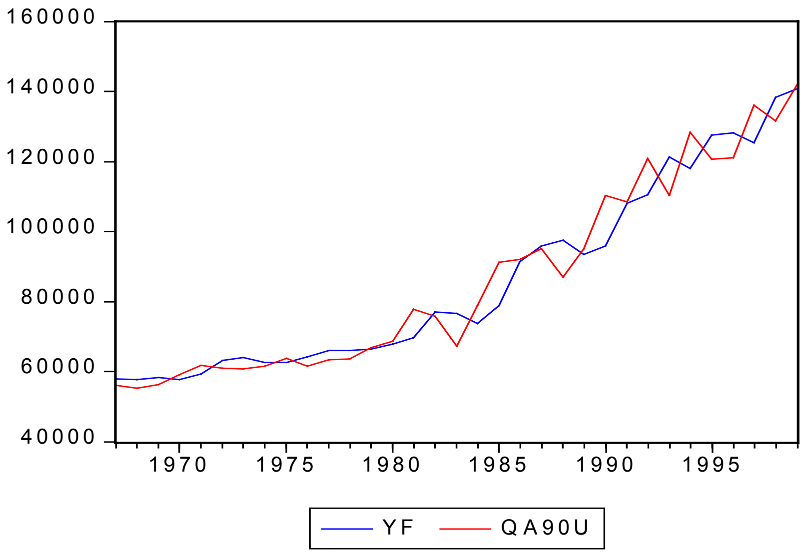
The equation expresses QA from supply side, and thus the expected signs are positive for lagged values of IPRA and QNA, because they represent good expectations for the sector, and negative for the lagged first difference of the log of QA, because years with high increases are usually followed by more moderate values in the following year. The coefficient of the lagged value is expected to have a value near to unity.

Equations 2.1 to 2.4 show the results for each country and equations 2.5 and 2.6 are two versions of the estimated equation for the pool sample of four countries.

Equation 2.1. LS Production equation in the USA 1967-99
Dependent Variable: LQA
Method: Least Squares
Included observations: 33 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIPRA(-1))	-0.067343	0.129190	-0.521267	0.6061
D(LQA(-1))	-0.341068	0.174310	-1.956677	0.0601
D(LQNA(-1))	0.789689	0.711953	1.109188	0.2765
LQA(-1)	1.001328	0.002187	457.8302	0.0000
R-squared	0.952765	Mean dependent var	11.31963	
Adjusted R-squared	0.947879	S.D. dependent var	0.308456	
S.E. of regression	0.070420	Akaike info criterion	-2.355453	
Sum squared resid	0.143812	Schwarz criterion	-2.174058	
Log likelihood	42.86498	Durbin-Watson stat	2.201708	

Graph 17. Fitted and actual values of QA90U

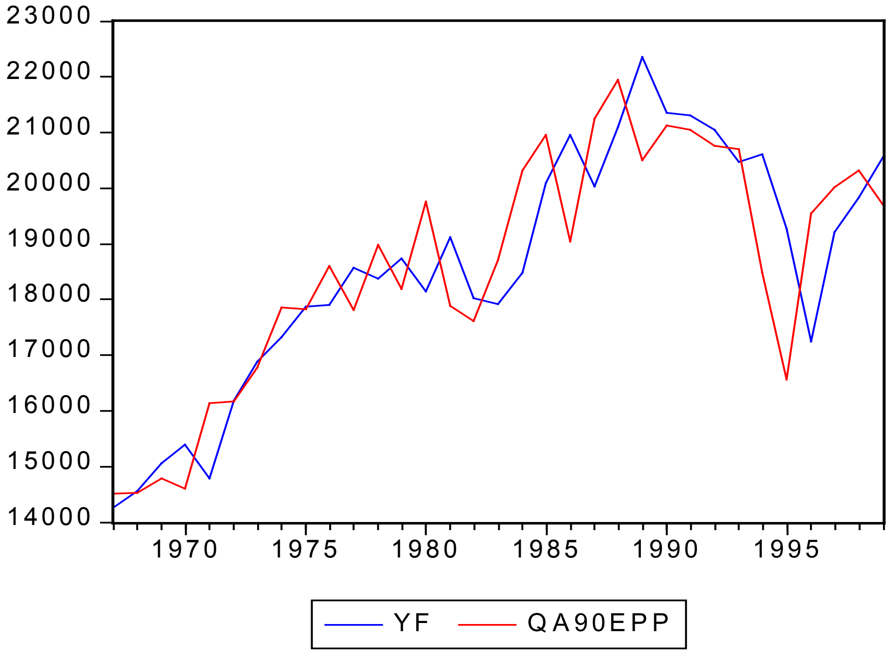


Equation 2.2. LS Production equation in Spain 1967-99
Dependent Variable: LQA
Method: Least Squares
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIPRA(-1))	0.155448	0.214768	0.723794	0.4750
D(LQA(-1))	-0.171429	0.192874	-0.888816	0.3814
D(LQNA(-1))	0.444303	0.486492	0.913280	0.3686
LQA(-1)	1.000167	0.002300	434.9174	0.0000

R-squared	0.742076	Mean dependent var	9.822687
Adjusted R-squared	0.715394	S.D. dependent var	0.119990
S.E. of regression	0.064013	Akaike info criterion	-2.546248
Sum squared resid	0.118832	Schwarz criterion	-2.364853
Log likelihood	46.01309	Durbin-Watson stat	2.247778

Graph 18. Fitted and actual values of QA90EPP

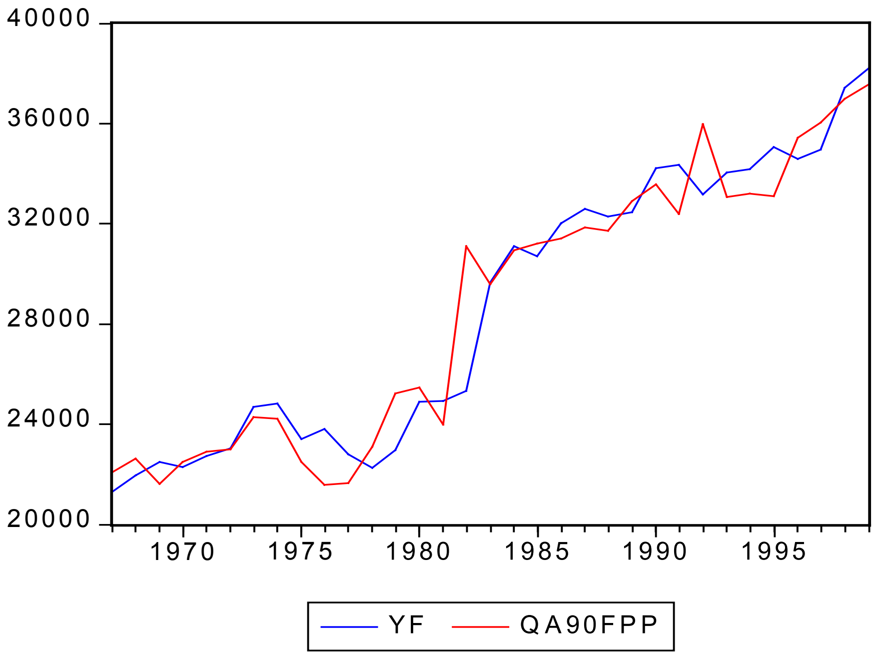


Equation 2.3. Production equation in France 1966-99
Dependent Variable: LQA
Method: Least Squares
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIPRA(-1))	0.433916	0.199271	2.177513	0.0377
D(LQA(-1))	-0.301282	0.162732	-1.851394	0.0743
D(LQNA(-1))	-0.538453	0.629480	-0.855393	0.3993
LQA(-1)	1.004918	0.002259	444.8443	0.0000

R-squared	0.922633	Mean dependent var	10.24401
Adjusted R-squared	0.914629	S.D. dependent var	0.193003
S.E. of regression	0.056392	Akaike info criterion	-2.799759
Sum squared resid	0.092222	Schwarz criterion	-2.618364
Log likelihood	50.19602	Durbin-Watson stat	1.977780

Graph 19. Fitted and actual values of QA90FPP

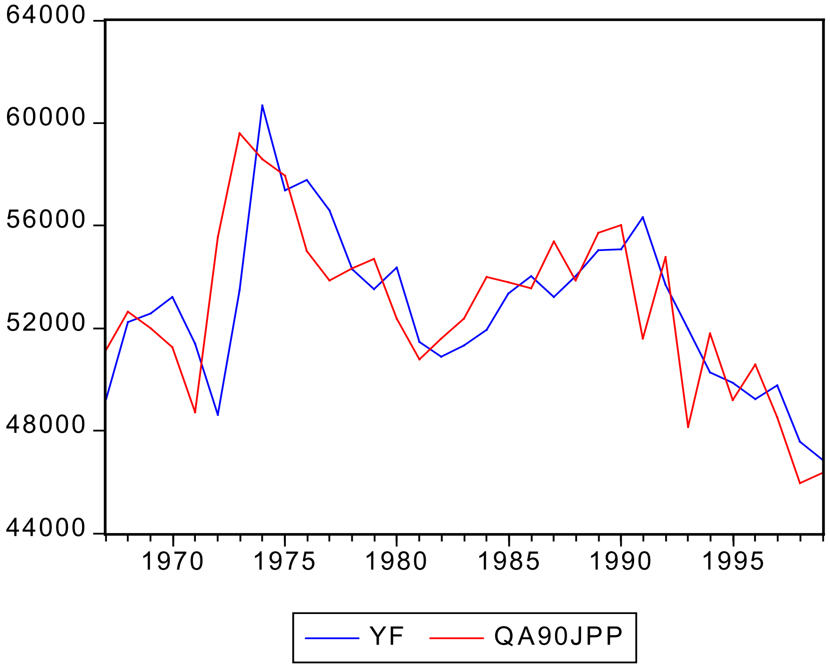


Equation 2.4. Production equation in Japan 1967-99
Dependent Variable: LQA
Method: Least Squares
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIPRA(-1))	0.300820	0.185372	1.622789	0.1155
D(LQA(-1))	-0.294502	0.177890	-1.655529	0.1086
D(LQNA(-1))	0.179658	0.259837	0.691425	0.4948
LQA(-1)	0.999357	0.001417	705.1748	0.0000

R-squared	0.465610	Mean dependent var	10.87186
Adjusted R-squared	0.410328	S.D. dependent var	0.061931
S.E. of regression	0.047557	Akaike info criterion	-3.140571
Sum squared resid	0.065588	Schwarz criterion	-2.959176
Log likelihood	55.81942	Durbin-Watson stat	1.944446

Graph 20. Fitted and actual values of QA90JPP



Equation 2.5. LS Production equation, Pool of 4 countries 1967-99

Dependent Variable: LQA
Method: Least Squares
Included observations: 132

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIPRA(-1))	0.105786	0.078227	1.352294	0.1787
D(LQA(-1))	-0.237939	0.086963	-2.736085	0.0071
D(LQNA(-1))	0.107808	0.212788	0.506646	0.6133
LQA(-1)	1.001533	0.000908	1102.543	0.0000

R-squared	0.990151	Mean dependent var	10.56455
Adjusted R-squared	0.989920	S.D. dependent var	0.607233
S.E. of regression	0.060966	Akaike info criterion	-2.727158
Sum squared resid	0.475761	Schwarz criterion	-2.639800
Log likelihood	183.9924	Durbin-Watson stat	2.081908

White Heteroskedasticity Test:

F-statistic	1.654820	Probability	0.116207
Obs*R-squared	12.82669	Probability	0.117953

The goodness of fit is high in all the cases, from the point of view of the percentage that the standard error of regression represents on the mean of dependent variable which is below 7% in all the cases.

The coefficient of determination is near unity in the pooled regression, and the estimated coefficients have the expected signs. There is not problem of heteroskedasticity according to the results of White´s test.

The hypothesis of coefficient of the lagged value of dependent variable equal to unity is rejected with the t of Student statistic:

$$t = (1.001533 - 1) / 0.00098 = 16.88 > t_{\alpha/2}$$

Thus there is evidence in favour of a supply trend towards increase in spite of the diminution of relative prices of agriculture, and the increase in non-agrarian production also seems to influence a positive increment in production from the demand side.

Although the coefficient of QNA is not significantly different from zero, the results are not due to the acceptance of the hypothesis of nullity but to a degree of uncertainty, with a wide interval of confidence for the parameter due to multicollinearity. This uncertainty would probably disappear with a bigger sample and the null hypothesis could then be rejected.

Regarding the possible contemporaneous interdependence between Production and Price we have not found general evidence in favour of that hypothesis, although there may sometimes be an effect on some agriculture products. This question is analysed in Guisan and Esposito(2003).

Finally we test, satisfactorily, the hypothesis of homogeneity of coefficients in the equation of real Value-Added of Agriculture, among the four countries included in the sample.

Homogeneity of coefficients Tests

The homogeneity of coefficients among countries in both production equations has been tested according to the corresponding tests based on the distribution F of Snedecor (see Guisan(1997) p.162), with the following results based on the Sum of Squares of Residuals, SSR of equations 2.1 to 2.5.

S_1 = SSR1 + SSR2 + SSR3 + SSR4 = 0.143812 + 0.118832 + 0.09222 + 0.065588 =

= 0.420454; degrees of freedom of S_1: $df_1 = 4*(34-4) = 120$

S_3 = SSR of join regression = 0.475761; degrees of freedom of S_3: $df_3 = 4*34-4=132$

$\Delta_3 = S_3 - S_1 = 0.055297$; degrees of freedom: $n_3 = 132 - 120 = 12$

$$F_3 = (\Delta_3/n_3) / (S_1/df_1) = 0.004681/0.0035038 = 1.34 < F_\alpha$$

The critical values of the F-Distribution, for 12 degrees of freedom in the numerator and 132 in the denominator, are 1.75 and 2.18, respectively, for values of α=0.05 and 0.01. Thus the hypothesis of homogeneity of coefficients among the 4 countries can be accepted, and equation 2.5 seems to be a good approach for explaining the evolution of real production in Agriculture.

Besides this model we have analysed other interesting relations between prices and quantities in this sector and we have found that there is empirical support for the hypothesis that the diminution in relative prices sometimes induces increases in production as a way of maintaining real income despite that diminution.

In Guisan and Exposito(2003) we analyse bilateral causality between real production and relative prices of Agriculture, both through a recursive system, without contemporaneous relationships, and through a simultaneous equation model to account for possible contemporaneous interdependence.

6.- Conclusions

We have analysed a general view of the technological transformation of Agriculture in OECD countries during the second half of the 20th century, and this leads us to present some interesting conclusions although a more detailed analyses would increase our level of knowledge on the evolution of this sector.

1) The technological transformation of Agriculture increased the level of average productivity of labour by a large degree due to the use of greater quantities of other important inputs such as machinery and research and development expenditures. Although the general trend of real production has been positive the general trend of real income has been negative due to the significant diminution of relative prices of Agriculture.

2) There was an important diminution in agrarian employment at the same time as an increase in non-agrarian employment so the non-agrarian sectors were able to absorb redundant workers from agrarian activities. This circumstance is essential for avoiding a socio-economic crisis that could occur in less developed countries if the technological revolution that they are going to confront over the coming decades is not properly accompanied by economic policies for economic growth in non-agrarian sectors.

3) Model 1 presents a high degree of goodness of fit for explaining the evolution of employment in agrarian activities, which is positively related with agrarian real income and negatively related with the non-agrarian one.

4) Model 2 shows good results for explaining the evolution of real production in Agriculture. The increase in demand, represented here by the evolution of non-agrarian production, shows a positive effect on supply. Increases in the lagged values of relative price also show a positive effect on supply.

5) Some contradictory results in economic literature regarding the causal relations between research and development expenditures and total factor productivity could be due to methodological problems caused by some limitations and uncertainty with the co-integration approach.

6) Agriculture production plays an important role in economic growth, not only through external trade, which favours a diminution of imports and an increase of exports, but also through an increase of production in non-agrarian sectors from demand and supply sides.

7) Subsidies for maintaining employment in agrarian activities are justified in our opinion, from a socio-economic point of view, especially when they are focused on increasing food quality. Over-substituting labour with other inputs can have serious repercussions on the quality of life both of farmers and consumers, by implying worse average quality, without increasing the real income of farmers.

8) Economic policies for the evolution of Agriculture in the USA, the European Union and other industrialised countries should place more emphasis on quality of production than on technology focused on price diminution. This is particularly important in the case of the EU where European bureaucracy is very distant from public opinion and from the reports of many academic researchers who very often advise changes in the direction proposed.

9) Technological transformations in Agriculture in less developed countries are producing positive and negative effects on their economic growth process, so international co-operation ought to be improved in our opinion, in order to diminish the negative effects and to improve the positive ones and to avoid unemployment and poverty in many areas.

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