MODELS OF PRODUCTIVITY IN EUROPEAN UNION, THE USA AND JAPAN

RODRÍGUEZ GONZÁLEZ, Xosé Antón
EXPÓSITO DÍAZ, Pilar
University of Santiago de Compostela (Spain)

Abstract

In this paper, three types of model are used for measuring productivity at the country level: a non-parametric model based on economic growth, an econometric model based on a Cobb-Douglas type production function, and a third procedure combining both parametric and non-parametric techniques.

These models are applied to the private sectors of European Union Countries (15), the United States, and Japan in the period 1983-2000. The findings indicate that the three models do not provide substantially different results. The countries analysed show remarkably different productivity growth patterns, and , moreover, he optimal growth pattern is the one in which growth is accompanied by increases in employment. Those countries that present both productivity growth and increased employment , have generally made an important investment effort both in education and research over the final decades of 20th century.

*JEL classification:*C23, 047
Keywords: productivity models, European productivity, Japan productivity, USA productivity

1. Introduction

How and why does the economy of a country or a particular industry grow? A fundamental explanation may be found in the behaviour of productivity. Productivity growth is necessary in order to improve a country's competitiveness and create wealth. In the opinion of some authors, as for example Krugman (1994, p13), productivity is the engine that propels improvement in the standard of living. Thus, the appropriate measurement of the productivity evolution is of significant interest.

An alternative to the direct calculations of productivity indexes is the estimation of production technology or productivity structure by elaborating econometric models based on production or cost functions. This analytical tendency began in the mid 1950's and intensified over the 70's and the 80's as a result of the abundance of serious empirical research. The first functions to be used were Cobb-Douglas and CES (Constant Elasticity of Substitution),which were widely used in economic analysis especially in studies on productivity and economic growth. The Cobb-Douglas production function was the pioneering tool in quantifying technical changes by means of an econometric estimation process.

From a practical standpoint, the use of Cobb-Douglas functions has some clear limitations. An especially noteworthy limitation is the implicit restriction of assuming that substitution elasticity is unitary for factors of production, which considerably reduces its range of applicability. This circumstance favours the use of CES functions which are more generic (in fact, Cobb-Douglas are simply a particular example of these). CES functions do not require substitution elasticity to be unitary and, thus, allow for broader empirical application.

Although CES functions are clearly superior to the Cobb-Douglas type in terms of generalisation, they too pose important problems that have been specified by Nadiri (1970). That is, from the empirical evidence (disparate results) it can be inferred the parameters of these functions are very sensitive to small data modifications, variable measurements, and estimating methods. In addition, it only considers two factors, because attempts to include more factors require the introduction of restrictions in terms of partial substitution elasticity. Most of the authors that have used these functions also mention the lack of flexibility to identify the determining sources of productivity.

Given the limitations and restrictions of working with the above functions, numerous attempts have been made to define functions which are more generic and flexible. Noteworthy among these has been the translog function introduced by Christensen-Jorgensen-

Lau(1971),which reached its heyday in the 1970's in the field of total productivity. Some of the most noteworthy studies using translog functions are the following: Berndt and Christensen's(1973),Berndt and Wood's(1975),and, Christensen and Greene's(1976).

Translog functions are a second order approximation for an arbitrary production (or cost) function which encompasses a group of functions (such as CES and ,therefore, Cobb-Douglas).Thus, translog functions have a generic nature which make them applicable to a variety of production contexts, even without prior information on the specific functional form.

Despite the theoretical superiority of translog functions, their practical use at the country our regional level is questionable because of their much greater need for data than Cobb-Douglas functions. This fact together with simplicity of use make Cobb-Douglas functions (after some adjustment of their initial form) highly useful for studying a country's productivity and growth. Therefore, the use of Cobb-Douglas functions in this empirical study at the country level is clearly justified.

The present study is organised in the following way: section 2 analyses some theoretical considerations regarding the methodology for measuring productivity, then section 3 presents our empirical results, and finally we present the most relevant conclusions to be drawn.

2. Methodology

A representative example of the empirical applications carried out at the country level throughout the 20th century are available in the book by Pulido, 2000. The following studies are notable examples: Douglas(1948), Abramovitz(1956), Solow(1957), Brown(1966), Abramovitz 1989),The World Bank (1993), Dowling and Summers (1997), and The European's Commitee's Research(1997). Aggregate production functions, a basic area of study in classic orthodox economics, are at the methodological core of the majority of these studies.

From the empirical applications studied, we can deduce at least three basic methodologies for use at the country level: non-parametric models (based on accounting growth), parametric models (based on aggregate production or cost functions), and procedures that combine both parametric and non-parametric techniques. These three types of model offer the fundamental advantage of only requiring limited sample information: production data as well as the factors of production capital and labour.

In order to present these procedures in a concise way, we part from the simplest version of an aggregate production function, through which we correlate the amount produced by a particular economy (Q) with the amounts of the basic factors of production, labour (L),and capital (K), in such a way that Q = f(L,K,t), with (t) being a proxy variable for technical change. Assuming that (t) is Hicks-neutral, the previous function can be expressed as follows:

$$Q= A(t)\, f(L, K) \qquad (1)$$

where the term A(t) can be interpreted as (given certain assumptions) as a measure of technological progress or total productivity.

Deriving (1) with respect to time, dividing the result by Q and reorganising the resulting terms, the following growth equation is obtained for the economy in question:

$$\hat{Q} = \hat{A} + e_{QL}\,\hat{\mathrm{L}} + e_{\mathrm{QK}}\,\hat{\mathrm{K}} \qquad (2)$$

where (^) represents growth rates of the corresponding elements, and e_{QL} and e_{QK} are the respective output elasticities for labour and capital.

In Solow's pioneering study (1957), a Cobb-Douglas type production function is assumed:

$$Q = A(t)\, \mathrm{L}^{a}\ \mathrm{K}^{b} \qquad (3)$$

assuming, in addition, a state of competitive equilibrium (in which each factor is remunerated according to the its marginal productivity),and constant returns to scale, which yields an accounting equation of the well-known Solow residual.

$$\hat{A} = \hat{\mathrm{Q}} - a\, \hat{\mathrm{L}} - (1-a)\, \hat{K} \qquad (4)$$

and its discrete version:

$$\frac{\Delta A}{A} = \frac{\Delta Q}{Q} - a\, \frac{\Delta L}{L} - (1-a)\frac{\Delta K}{K} \qquad (5)$$

Equation (5) expresses the contributions to growth in the usual terms of the neo-classical approach. Thus, variations in growth can be explained by changes in production factor utilisation (weighted by their relative income share), and by gains in total productivity. This equation also indicates that gains in total productivity can be calculated as the difference between output growth and the growth of the weighted factors. From an empirical point of view, the calculation of equation (5) is subject to two important restrictions. First, it assumes constant returns to scale and, second, it assumes that each production input is weighted according to its income share.

When we use time series data for countries or regions, an alternative to equation (5) can be used. This alternative specifies an econometric model based on equation (3) by including a parameter to quantify technical change and the corresponding random disturbance:

$$A_{it} = e^{d_i t + e_{it}} \qquad (6)$$

such that:

$$Q_{it} = L_{it}^{a} K_{it}^{b} e^{d_i t + e_{it}} \qquad (7)$$

that is easily linearized as:

$$\ln Q_{it} = d_i\, t + a \ln L_{it} + b\, K_{it} + e_{it} \qquad (8)$$

where d_i measures, for each country or region, its total productivity as the average rate of production growth when the amount of factors employed remains constant. The use of (8) offers the advantage of not requiring constant returns to scale. On the other hand, it has the disadvantage of not yielding significant coefficients when a high number of regions or countries are studied.

A third alternative for measuring the evolution of productivity consists of estimating (based on equation 3) the values of a and ß and then, in a second step, calculating productivity growth for each country and year by applying equation (5). This third procedure does not require constant returns to scale, but makes it possible to check if they exist. It also clarifies if the participation of each input corresponds to its share income. Furthermore, it is also possible to calculate total productivity.

These three calculation procedures are applied to the private sector economies of EU countries, the USA, and Japan. This study excludes non-market goods and services in to carry out a more uniform analysis.

3.Empirical results

We begin the empirical analysis by presenting table 1 which shows the average values for the growth rate of value added (VA), employment and capital in the private sector the above mentioned countries in the period 1983-2000. As can be observed, the behaviour of these three variables in the three economic areas is quite different. The European Union has a characteristically high average growth in VA, a very moderate growth in employment and a significant growth in capital (with important differences in growth rate among EU countries). In contrast, Japan offers a very moderate growth in VA, a high growth in capital, and a small decrease in its average employment. The United States presents the most stable growth in all three variables, with averages around 1.5- 2%.

Table1.Growth rates for VA, employment, and capital (expressed as a percentage). Average rates for the period 1983-2000 .

Country	Value added	Employment	Capital
Germany (AL)	2.54	0.34	1.33
Austria (AT)	2.34	0.22	3.30
Belgium (B)	3.74	0.19	2.09
Denmark (D)	4.32	0.45	1.19
Spain (E)	5.06	0.80	2.09
France (F)	2.94	0.30	0.72
Finland (FI)	3.77	-0.57	1.06
Greece (GR)	7.51	0.50	0.05
Ireland (IR)	7.05	2.50	2.62
Italy (IT)	4.49	-0.70	1.54
Luxembourg (L)	4.69	1.66	4.55
Netherlands (NE)	2.26	1.20	1.79
Portugal (PT)	7.12	0.16	2.60
Sweden (SE)	4.82	2.05	1.01
United Kingdom (UK)	3.27	1.44	2.22
European Union (UE)	3.48	0.50	1.50
United States (USA)	1.92	2.07	1.55
Japan (J)	0.46	-0.19	3.41

Source: Database Penn World Tables 6.0

As can be seen in graph 1, the evolution of VA, employment, and capital in the three economic areas over time is not homogenous. The United States presents the most stable growth, the European Union shows a fall in employment in the early 90's and then a recovery starting in 1994, while Japan experiences a significant fall in employment and VA in the early 90’s which continues to end of the period analysed.

Graph 1. Evolution of VA, employment and capital in the EU, the USA and Japan.

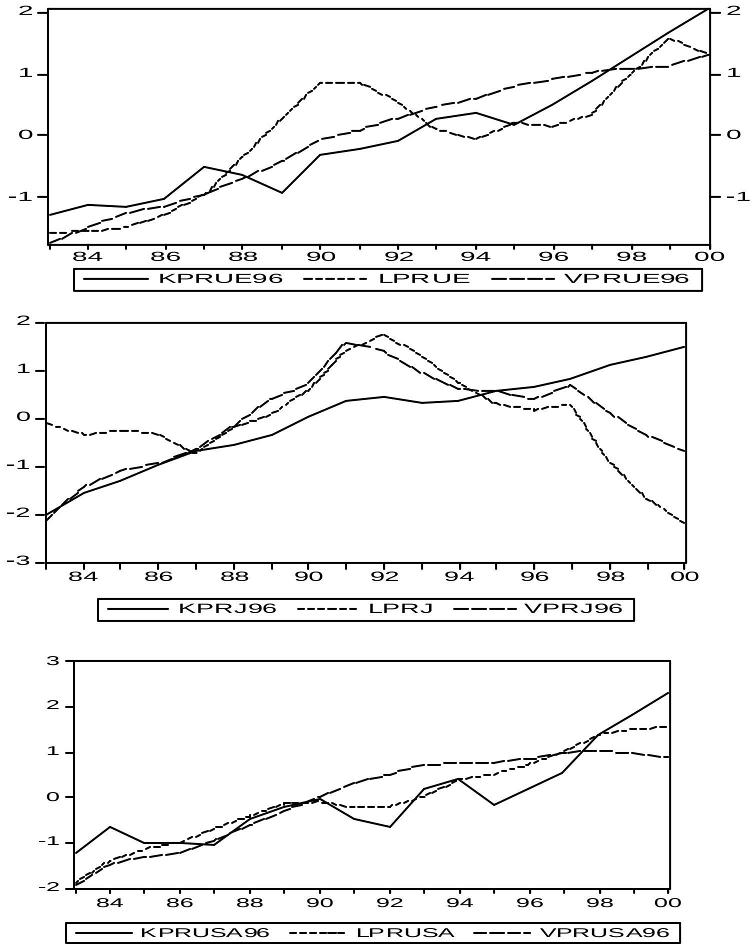

Table 2 presents the partial productivity levels of employment, capital and capital/employment ratios, as well as their average growth rates. Comparing the three economic areas, the United States has the highest productivity levels of employment and capital, while the European Union has the lowest average levels of these indicators.

The growth rates of partial productivity generally follow an opposite trend from their initial levels (the greater the partial productivity the less growth). An exception can be found in the growth in the partial productivity of capital in Japan. which underwent a negative average growth rate due to considerable growth in input of capital during the period. The capital/employment ratio follows a completely different growth pattern. In this indicator, Japan presents the highest levels and the highest, while the USA presents the lowest levels and the lowest rates of growth. Partial productivity and capital/employment ratios as well as their growth vary greatly within the EU.

Table 2. Ratios for employment/VA, capital/VA, capital/employment and their growth rates (in percentages).Average rates for the period 1983-2000.

Country	VA/Emp (1)	VA/Cap (2)	Cap./Emp (3)	(VA/Emp.) %	(VA/Cap) %	(C./E.) %
(AL)	41.115	3.713	11.057	2.20	1.23	1.01
(AT)	38.586	4.286	9.047	2.13	-0.85	3.08
(B)	52.000	4.117	12.537	3.54	1.71	1.91
(D)	41.530	3.624	11.451	3.88	3.34	0.76
(E)	37.306	4.917	7.531	4.27	2.98	1.25
(F)	49.588	4.143	11.946	2.67	2.27	0.45
(FI)	38.243	2.991	12.626	4.49	2.78	1.75
GR)	25.677	3.913	6.65	6.99	7.72	-0.43
(IR)	38.776	4.735	8.193	4.51	4.41	0.19
(IT)	40.556	4.270	9.360	5.27	2.96	2.30
(L)	61.143	7.825	7.832	3.02	0.23	2.84
(NE)	41.059	4.543	9.053	1.08	0.58	0.60
(PT)	20.775	4.410	4.633	6.88	4.74	2.37
(SE)	28.976	3.950	7.570	2.82	3.91	-0.85
(UK	31.823	4.748	6.717	1.84	1.20	0.82
(UE)	38.867	4.166	9.295	2.97	2.00	1.00
(USA)	63.599	7.643	8.342	-0.13	0.45	-0.50
(J)	49.904	5.030	10.117	0.65	-2.83	3.62

Source: Database Penn World Tables 6.0

Notes: (1) Thousands of dollars per employee (dollars expressed in 1996 purchasing power parity). (2) Dollars expressed in 1996 purchasing power parity (3 Thousands of dollars per employee (dollars expressed in 1996 purchasing power parity).

The first two columns of table 3 present the participation of capital and employment in VA according to the relative income shares. We can see that the average contribution of each is similar (51% for capital vs. 49% for employment), while in the USA and Japan the contribution of capital is somewhat higher (53% vs. 47%). Within the European Union, the variations of the proportions are more marked. For example, in Greece capital makes up 79%, whereas in the United Kingdom, employment makes up 57%.

The income share in production processes does not necessarily have to be the same as the contribution of the inputs to production. One way of approaching this contribution is to estimate elasticities for employment and capital in the production function (3). These estimations (of a and ß) are presented in columns 3 and 4 of table 3. Several interesting points can be deduced from its analysis:

- Estimated elasticities clearly diverge from the participation in VA.
- According to the elasticity estimations, employment presents a higher contribution than capital, while capital income is generally higher.
- In the countries analysed (except for Luxembourg) the assumption of constant returns to scale is not met.

The two final columns of table 3 present the rates of total factor productivity (TFP) In (a) the weighting is the contributions of factors to VA (model 5) and in (b) the weighting is the estimated elasticities (model 5 without the assuming constant returns to scaled). From the results obtained using these two ways of modelling TFP growth, the following is worth mentioning:

-The two procedures yield different quantitative results, given the markedly divergent weighting of factors, however, the differences are not as great as might be expected mostly because the growth of labour (with a greater estimated elasticity) is relatively small (table 1).

- For the EU (that presents the lowest average productivity levels of employment and capital, the highest growth rate in VA ,and a limited average growth for employment, according table 2) we estimated the greatest TFP growth rates, at an average of about 2.5%.

- For the case of the USA (that has the highest levels of partial elasticities for employment and capital and a considerable average growth in employment) the estimated average TFP growth over the period was nearly zero or negative.
- The estimation for Japan using both procedures is for a decrease in TFP mainly because of weak growth in VA and sharp growth in capital.
- Within the EU, both procedures yield positive growth rates for all countries, especially for Greece, Portugal and Ireland.

Table 3. Contributions to value added, estimated elasticities and growth rates (expressed as percentages) of the Total Factor Productivity (TFP) according to contributions (a) and elasticities (b). Average for the period 1983-2000. K= capital, L= Employment

	Contributions to V.A.		Estimated elasticities (1)		Growth rates of TFP	
Country	K	L	C	L	Con.VA (a)	Elastic (b)
AL)	0.48	0.52	0.37	0.92	1.75	1.73
AT)	0.50	0.50	0.17	1.25	0.58	1.50
(B)	0.47	0.53	0.05	1.67	2.64	3.31
(D)	0.46	0.54	0.15	1.36	3.53	3.54
(E)	0.58	0.42	1.10	0.05	3.45	2.71
(F)	0.48	0.52	0.29	1.05	2.46	2.42
(FI)	0.48	0.52	0.79	0.51	3.63	3.23
GR)	0.79	0.21	0.20	1.33	7.34	6.84
(IR)	0.54	0.46	0.39	0.85	4.59	3.91
(IT)	0.61	0.39	0.88	0.33	3.83	3.37
(L)	0.52	0.48	0.86	0.10	1.41	0.60
(NE)	0.50	0.50	0.31	1.04	0.78	0.45
(PT)	0.58	0.42	0.13	1.28	5.46	6.44
(SE)	0.44	0.56	0.54	0.76	3.21	2.72
(UK)	0.43	0.57	0.29	1.01	1.50	1.17
(UE)	0.51	0.49	0.28	1.00	2.48	2.56
(USA)	0.53	0.47	0.04	1.33	0.15	-0.89
(J)	0.53	0.47	0.22	1.03	-1.26	-0.09

Source: Database Penn World Tables 6.0
Note: (1) The null hypothesis of constant returns to scale is rejected (at the 5% level) in the countries analysed, except for Luxembourg.

An alternative to the two models previously mentioned for measuring the evolution of productivity consists of estimating model (8). This model has been estimated using panel data techniques, assuming that differences across countries can be captured by differences in constant term (d_i measures, for each country or region, its total productivity as the average rate of production growth when the amount of factors employed remains constant). We use a feasible generalized least square (GLS) method considering both cross-section heteroskedasticity and comtemporaneous correlation.

The results are presented in table 4. The average productivity growth rates for each country are generally a good reflection of the growth trends described by the 2 previous procedures. For the EU countries (with the exception of France) positive average rates are found, especially in the case of Ireland. Divergences from the 2 previous procedures are mainly due to the fact that for six of the European countries analysed the coefficient found are not statistically significant at the usual level of 5%, as for example the case of France. For the cases of the USA and Japan, this model confirms the estimation of negative rates, although it over estimates the decrease with respect to both previously described procedures.

Table 4. Model estimation

Dependent Variable: LOG(VPR?96)				
Method: GLS (Cross Section Weights)				
Sample: 1983 2000				
Included observations: 18				
Number of cross-sections used: 17				
Total panel (balanced) observations: 289				
Convergence achieved after 17 iterations				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(LPR?)	1.004011	0.052300	19.19715	0.0000
LOG(KPR?96)	0.344240	0.041158	8.363871	0.0000
AL	0.020017	0.006912	2.896088	0.0041
AT	0.009426	0.006654	1.416644	0.1577
B	0.030390	0.007559	4.020264	0.0001

D	0.030369	0.008004	3.794129	0.0002
E	0.002549	0.008779	0.290300	0.7718
F	-0.002396	0.006462	-0.370860	0.7110
FI	0.030444	0.007949	3.830139	0.0002
GR	0.028262	0.004456	6.343174	0.0000
IR	0.039111	0.009730	4.019803	0.0001
IT	0.004045	0.006507	0.621585	0.5347
J	-0.029781	0.006153	-4.840210	0.0000
L	0.007797	0.001309	5.954065	0.0000
NE	0.001707	0.007638	0.223430	0.8234
PT	0.014893	0.007223	2.061777	0.0402
SE	0.004829	0.007531	0.641278	0.5219
UK	0.023642	0.006435	3.674062	0.0003
USA	-0.028184	0.007646	-3.686078	0.0003
AR(1)	0.925099	0.012125	76.29984	0.0000
Weighted Statistics				
R-squared	0.999990	Mean dependent var		16.69939
Adjusted R-squared	0.999989	S.D. dependent var		11.18194
S.E. of regression	0.037169	Sum squared resid		0.371637
F-statistic	1371837.	Durbin-Watson stat		1.432297
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.999497	Mean dependent var		12.29221
Adjusted R-squared	0.999462	S.D. dependent var		1.601764
S.E. of regression	0.037169	Sum squared resid		0.371638
Durbin-Watson stat	1.337585			

Given the productivity growth patterns, we can pose two interesting questions: which is the best possible productivity growth patterns, and which factors make the development of this patterns possible? The answer to the first question seems clear. The best patterns is the one followed by those countries in which productivity grows and employment grows (if unemployment is at a level that can be reduced) because these two circumstances make it possible for an economy to be more competitive while improving welfare levels. Ireland is the prototypical example, as it maintained an average productivity growth around 4% over the period studied and had the highest average growth in employment (2.5%). To a lesser extent, this framework was also followed by countries such as Sweden, the Netherlands, Luxembourg, the United Kingdom and Spain.

The second question does not have such a clear answer. To approach this question we can refer to some very interesting quantitative studies in the field of economic growth and development factors such as the following: Guisan & Arranz (2001),Guisán et al.(2001),Guisán & Neira (2001),Neira & Guisán (2002),Guisán et al.(2004), in which it is pointed out that investment in education and research are important factors to promote economical growth and development. The countries which attain improvements in productivity and job creation are precisely those that have made considerable investment efforts in the last decades of the twentieth century.

4.Conclusions

A rather broad consensus exists regarding the assertion that productivity growth is necessary for the creation of wealth and the improvement of a country's competitiveness. Thus, an adequate measure of productivity growth behaviour is very important. The present study proposes three procedures for measuring total productivity, which do not yield substantially different results in so far as productivity trends in the countries analysed. Nevertheless, the method combining both parametric and non-parametric techniques has proven to be the most complete.

The results obtained make it clear that not all productivity growth patterns are the same and that their consequences also differ. It would seem logical to assert that total productivity growth accompanied by improvement in employment is desirable because this can guarantee advances in social welfare. Those Countries that have implemented this patterns are generally those that have made important investment efforts in education, research and development in the last decades of the 20th Century.

Bibliography

Abramovitz, M. (1956). “Resource and output in the United Status since 1870”, *American Economic Review. Papers and Proceedings*, may, pp. 5-23. Included in Rosemberg, N. editor, *The economics of technological change*, Penguin, 1971, pp. 320-343.
Abramovitz, M. (1989). *Notes on post-war productivity growth. The play of potential and realisation*. OCDE, International Seminar on Science, Technology and Economic Growth, June
Brown, M. (1966). *On the theory and measurement of technological change*, Cambridge University Press.
Berndt, E. R. and Christensen, R. (1973). “The Translog Funtion and the Substitution of Equipament, Structures and Labor in U. S. Manufacturing, 1929-68”, *Journal of Econometrics*, vol. 1.
Berndt, E. R. and Wood, D. O. (1975). “Technology, Prices and the Derived Demand for Energy”, *Review of Economic and Statistics*, vol. 57.
Christensen, R.; Jorgenson, D.W.; Lau, L.J. (1971). “Conjugate Duality and the Transcendental Logaritmic Production Funtion”, *Econometrica*, vol. 39, nº 4.
Christensen, R. and Greene, W.L. (1976). “Economies of Scale in Electric Power Generation”, *Journal of Political Economy*, vol. 84, nº 4.
Commission of the European Communities (1997). *Annual Economic Report. Growth, employment and convergence on the road to EMU*, December.
Douglas, P. H. (1948). “Are there laws of production?”, *American Economic Review*, vol. 38, pp. 1-49.
Dowling, M. and Summers, P. (1997). *Total factor productivity and economic growth. Issues for Asia*, Link meeting, Kuala Lumpur.
Guisán, M.C. y Arranz, M. (2001). Consumption Expenditure on Health and Education. Documento de la serie *Economic Development*, nº 54[1]

Guisán, M.C.; Cancelo, M.T.; Neira, I.; Aguayo, E. y Expósito, P.(2001). *Crecimiento económico en los países de la OCDE. 1 Modelos de crecimiento y empleo en Irlanda, Francia, España, Alemania USA y Japón*. Estudios Económicos Asociación Hispalink-Galicia. Santiago de Compostela.

Guisán, M.C. y Neira, I (2001). "Capital humano y capital físico en la OCDE, su importancia en el crecimiento económico en el periodo 1965-95", *Estudios Económicos de Desarrollo Internacional*, vol. 1, nº 2, pp.61-83.

Guisán, M.C.; Cancelo, M.T.; Neira, I.; Aguayo, E. y Expósito, P.(2004). *Crecimiento económico en los países de la OCDE. 2 Modelos macroeconométricos y factores de desarrollo en Europa, USA, Japón, México y otros países, 1960-2000*. Estudios Económicos Asociación Hispalink-Galicia. Santiago de Compostela.

Krugman, P. (1994). *Vendiendo prosperidad*. Editorial Ariel. Barcelona.

Pulido, A. (2000). *Economía en acción*. Ediciones Pirámide, Madrid.

Neira, I. y Guisán, M.C. (2002). Modelos econométricos de capital humano y crecimiento económico: efecto inversión y otros efectos indirectos, Documento de la serie Ecoomic Development nº 62[1].

Solow, R. (1957). "Technical change and the aggregate production function". *Review of Economics and Statistics*, August, pp. 312-320. Included in Rosemberg, N. editor, *The economics of technological change*, Penguin, 1971, pp. 344-362.

(1) Documents on-line in : http://www.usc.es/economet

Journal published by the Euro-American Association of Economic Development. http://www.usc.es/economet/eaa.htm