Technology and Sector Clustering in the Greek Economy

Belegri-Roboli, Athena and Michaelides, Panayotis G.

2007

Technology and Sector Clustering in the Greek Economy

Athena Belegri-Roboli* *and* Panayotis Michaelides **

National Technical University of Athens
Faculty of Applied Mathematics & Physics
Laboratory of Applied Economics
9 Heroon Polytechneiou, Zografou, 15780, Greece
belegri@central.ntua.gr, pmichael@central.ntua.gr

Abstract: The aim of this paper is to identify the economic sectors in the Greek economy which are dynamic in terms of their technological characteristics expressing its economic perspectives. To do this, the paper uses the Clustering Analysis methodology for grouping the various sectors of economic activity in Greece. The twenty-one sectors of economic activity are thus assembled into clusters presenting similar technology characteristics and the empirical results are discussed. The technical analysis is based on Growth Accounting methodology to estimate technological change, as well as labor and capital productivity in the various sectors of the Greek economy over the period 1988-1998. The results show that the various sectors of economic activity tend to form three (3) distinct clusters experiencing similar technological and growth characteristics. Meanwhile, the technological level, as measured through annual growth in Total Factor Productivity, has remained practically unchanged. Finally, technological change accounts for about 40% of economic growth, which is slightly lower compared with the relative performance of other O.E.C.D. countries.

Key words: economic growth, technology, T.F.P., sector, cluster analysis, Greece.

* Mrs Athena Belegri-Roboli, PhD is Assistant Professor in Economics
** Mr. Panayotis Michaelides, PhD is Visiting Lecturer in Economics

1. Introduction

Greece is the most easterly country within Western Europe and the enlargement of the E.U. to the East creates a new allocation of resources. Consequently, factors such as productivity will play a decisive role for competitiveness. Nowadays, technological progress is a major driving force of long-term economic growth (O.E.C.D., 1996, p. 53). In fact, economic research has shown that technological progress accounts for the majority of long-term productivity growth (Tassey, 2004, p. 165).

In this context, the measurement of technological change for Greece, by sector of economic activity as well as the grouping of industries regarding their technological characteristics is of great interest since the country constitutes an original member of the O.E.C.D., and an old member of the E.U. Also, it ranks very high among E.U. countries in output growth since 1995. However, despite its high growth rates, Greece has long been viewed as one of the laggards within the E.U. In fact, it ranked last among E.U. members in R&D expenditures (E.C., 2003; E.C., 2000) and very low in terms of growth in T.F.P. (e.g. O'Mahony, 2002, p. 9).

Unless Greece can begin to do better, it will probably continue to be at the bottom of the E.U. distribution. After stabilizing the macroeconomic environment, the next stage for Greece is to accelerate the rate of increase in technological change. In this context, the E.C. report suggests that Greece should give high priority to taking measures to increase technology diffusion and financing (E.C., 2000, p. 31).

Obviously, the identification of poorly performing clusters of economic activity within the Greek economy could have significant policy implications. For instance, the analysis pinpoints the industries forming a cluster, the performance of which is poor and needs enhancement. On the other hand, the Greek government might wish to subsidize changes in a certain cluster and in this case, our analysis indicates the annual growth rates of each cluster's technological characteristics.

The purpose of the paper is to present estimates of total factor productivity (T.F.P.) change which accounts for technological change, as well as estimates of labor and capital productivity, by sector and cluster of economic activity. We use the *Growth Accounting* methodology for the case of Greece, over the period 1988-1998, when data are available. Continuously, we group the twenty-one sectors of economic analysis in Greece, into clusters of sectors sharing similar characteristics concerning technological change and growth. To this end, the paper uses the clustering analysis methodology which offers a reliable quantitative framework.

The remainder of the paper is structured as follows: section 2 sets out the methodological frameworks; section 4 presents the empirical results, while section 5 concludes the paper.

2. Methodology

With the aid of the relevant methodologies we are about to: (a) estimate the level of technological change in Greece by sector of economic activity, and (b) assemble the twenty-one sectors of economic activity in Greece into clusters presenting similar technology characteristics.

2.1 Technological Change Estimation

According to Rosenberg (1982: 3) technological change constitutes any change in the application of knowledge that can make it possible to produce (i) a greater volume of output from a given amount of resources, (ii) a qualitatively superior output, or (iii) a completely new output (Mokyr, 1990, p. 6; Jones, 1993, p. 190; Rosenberg, 1982, p. 3). Technology constitutes a very crucial determinant of the economy's competitiveness, however its quantification is difficult and it is usually estimated indirectly using a production function (O.E.C.D., 1996).

The use of an aggregate production function and its limitations are well understood by now, yet the methodological framework is a popular one. The empirical investigation is based on *Growth Accounting.* In *Growth Accounting* growth in an economic unit is decomposed using a production function into a part explained by growth in factor inputs and another part (the Solow residual), which is attributed to technological change (Total Factor Productivity-T.F.P.). Growth accounting has been applied to numerous cases in the last decades (e.g Denison, 1985; Jorgenson, 1988; Griliches, 1988; O'Mahony, 1992; Page, 1994; Young, 1994; Belegri-Roboli and Michaelides, 2006) with satisfactory results.

The most commonly used production function in empirical investigations using aggregate data is the unrestricted Cobb-Douglas (CD) production function (Thirlwall, 2001, p. 181). We assume a CD production function with two inputs (capital and labor) and Hicks-neutral technological progress. So, production at time *t* is given by:

$$Y(t) = A(t) \bullet L(t)^{a} \bullet K(t)^{\beta} \quad (1)$$

$$Y(t)>0,\ L(t)>0,\ K(t)>0,\ A(t)>0,\ \alpha>0,\ \beta>0$$

The notation is standard: Y is output, L labor, K capital and A the level of technology. Meanwhile, *a* and *b* are the parameters of the CD, expressing the elasticities of output with respect to labor and capital, respectively, and have to be estimated (Dornbusch and Fischer, 1993, p. 873). From equation (1) we get equation (2) which allows us to estimate technological change (Thirlwall, 1999, p. 181):

$$\dot{A} / A = \frac{\partial A(t)}{\partial t} \bullet \frac{1}{A(t)} = \frac{\partial Y(t)}{\partial t} \bullet \frac{1}{Y(t)} - \alpha \frac{\partial L(t)}{\partial t} \bullet \frac{1}{L(t)} - \beta \frac{\partial K(t)}{\partial t} \bullet \frac{1}{K(t)} \quad (2)$$

The percentage of economic growth, which is attributed to technological progress (π) is also calculated (Thirlwall, 2001, p. 189). The rates of growth of labor productivity (l) and capital productivity (k) are given by (Romer, 1996, p. 26):

$$l = \frac{\partial Y(t)}{\partial t} \bullet \frac{1}{Y(t)} - \frac{\partial L(t)}{\partial t} \bullet \frac{1}{L(t)} \quad (3)$$

$$k = \frac{\partial Y(t)}{\partial t} \bullet \frac{1}{Y(t)} - \frac{\partial K(t)}{\partial t} \bullet \frac{1}{K(t)} \quad (4)$$

2.2 Clustering Analysis

A general question in applied economics is how to organize observed data into meaningful structures and clustering has been used since long for grouping together entities with similar characteristics. Nowadays it has acquired increasing attention as a solution to the complexity related to voluminous datasets. The reason for its increased significance and convenience is that it relies on creating natural groups in the existing data rather than classifying them on the basis of some externally imposed criteria. These clusters presumably reflect some mechanism at work in the domain from which data are drawn; the mechanism causes some units of the cluster to bear a stronger resemblance to one another than they do to the remaining units (Aerts et *al.,* 2002)..

Consequently, the term *cluster analysis*, introduced in Tryon (1939), refers to an exploratory data analysis tool which aims at sorting different objects and data into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. Given the above, cluster analysis can be used to discover structures in data. So records with similar content are in the same group, and groups are as different as possible from each other (Kaufmann and Rousseeuw, 1990)

Excellent reviews of Clustering Algorithms have been provided by various researchers (e.g. Jain and Dubes, 1988; Kaufmann and Rousseeuw, 1990). However, the algorithms used differ in how they compute the distance between the two clusters. We use the Euclidean distance as a measure of similarity, which is the most commonly chosen type of distance (Jain and Dubes, 1988). Note that Euclidean (and squared Euclidean) distances are usually computed from raw data The Euclidean distance is the geometric distance. It is computed as:

$$\text{distance}(x,y) = \{ \textstyle\sum_i (x_i - y_i)^2 \}^{1/2} \quad (5)$$

There exist several algorithms (e.g. Nearest Neighbor, Furthest Neighbor, Centroid, Median, Group Average, Ward's, and *K*-Means) for grouping observations from a multivariate dataset into clusters of similar points. In the *K*-Means method (Glascoe et *al.*, 2004) formation of clusters begins with an initial partition then uses a search algorithm to test other partitions to identify the one with the least error. The *K*-means method is the most commonly used algorithm in this type of investigations. Also, it has a very important advantage, that the distance between any two objects is not affected by the addition of new objects to the analysis, which may be outliers (Statsoft, 2004). It was chosen because it is effective in using a heterogeneous high-dimensional multivariate data set to create a manageable set of relatively homogeneous classes which could be employed for issues of economic policy (Glascoe et al., 2004).

In *K*-means the observations are divided into *K* clusters in such a way that an objective function, i.e. the total sum of squared Euclidean distances between observations and their respective cluster centroids (average value of the observations) is minimized. The *K*-means algorithm minimizes the squared error function. The objective function is:

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \quad (6)$$

where $\left\| x_i^{(j)} - c_j \right\|$ is the chosen distance measure between a data point $x_i^{(j)}$ and the cluster centre c_j, is an indicator of the distance of the n data points from their respective cluster centers.

In the next section, the results from both methodologies are presented.

3. Empirical Analysis

The significance of the factors entering the production function of the various sectors of economic activity in Greece is tested using the available data collected from the publications of the National Statistical Service of Greece (2001, 2002). For the industry classification, see Table IV, Appendix. The data available is on an annual basis and covers the period 1988-1998. The regressions are based on the log-linear form of the Cobb-Douglas production function with two inputs, i.e. capital and labor, Hicks-neutral technological progress and are estimated with the aid of the Ordinary Least Squares (O.L.S.) methodology (see Table III, Appendix), which is the standard procedure for estimating the Cobb-Douglas production function (Stewart, 2005; Mankiw, Romer and Weil, 1992).

The signs of the estimated coefficients are consistent, except for one case, with the implied hypotheses (a>0, b>0) and are statistically significant, in most cases. The regressions account, in most cases, for a high percentage of the variability of output in the various sectors of economic activity in Greece, which, given the inevitable imperfections in the data, is satisfactory (Mankiw, Romer and Weil 1992, p. 408).

Continuously, the estimated parameters (a, b), the rates of growth in output ($\dot{Y} / Y$), labor ($\dot{L} / L$), capital ($\dot{K} / K$), labor productivity (l), capital productivity (k), total factor productivity ($\dot{A} / A$) and the percentage of output growth by sector of economic activity that is attributed to technological progress (π), are calculated (Table I).

A first conclusion that can be drawn is that for the great majority of sectors, T.F.P. remains, practically, unchanged (on average, equal to -0.39%), over the time period 1988-1998. This finding is, roughly speaking, consistent with estimates, for the total economy, by other researchers, such as O'Mahony (1992), Bosworth and Kollintzas (2001), O.E.C.D. (1996, p. 60). All these figures use slightly different methodologies (or data) and yield slightly different results. However, they all confirm the main conclusion, i.e. that in the late 80s and for the great part of the 90s, Greek T.F.P. remained, practically, unchanged.

Table I

Growth Rate in Output, Labor, Capital, Labor Productivity, Capital Productivity, Total Factor Productivity and Technology Participation for Greece, by sector (1988-1998).

Sector	a	b	a + b	$\dot{Y}/Y$	$\dot{L}/L$	$\dot{K}/K$	l	k	$\dot{A}/A$	p
1	0,170	0,048	0,218	0,0077	0,0285	0,0804	-0,0208	-0,0726	-0,001038	**0,13402**
2	0,350	0,146	0,498	-0,0098	0,0137	-0,0513	-0,0234	0,0416	-0,006996	**0,71760**
3	0,610	0,014	0,625	0,0175	0,0389	-0,2418	-0,0214	0,2592	-0,002823	**0,16172**
4	0,233	1,203	1,437	-0,0102	-0,0058	-0,0062	-0,0044	-0,0040	-0,001356	**0,13288**
5	0,708	0,047	0,756	-0,0045	0,0176	-0,2803	-0,0220	0,2759	-0,003619	**0,83168**
6	0,529	0,436	0,965	0,0389	0,0571	0,0305	-0,0182	0,0085	-0,004586	**0,11779**
7	0,762	0,856	1,619	0,0077	0,0470	-0,0153	-0,0393	0,0230	-0,015005	**1,93907**
8	-0,37	0,554	0,187	0,0013	0,0279	0,0265	-0,0265	-0,0252	-0,003124	**2,34710**
9	1,674	0,532	2,206	0,0230	0,0291	-0,0416	-0,0061	0,0646	-0,003523	**0,15310**
10	0,389	0,797	1,187	-0,0107	0,0961	-0,0657	-0,1069	0,0549	0,004195	**0,38961**
11	1,066	0,114	1,182	0,0176	0,0395	-0,2367	-0,0220	0,2543	0,002582	**0,14688**
12	0,112	0,230	0,343	0,0109	0,0010	0,0404	0,0100	-0,0295	0,001499	**0,13733**
13	0,591	0,028	0,620	0,0371	0,0508	0,2188	-0,0137	-0,1817	0,000775	**0,02088**
14	0,502	0,467	0,970	0,0381	0,0390	0,0250	-0,0009	0,0131	0,006803	**0,17855**
15	0,013	0,376	0,391	0,0436	0,0566	0,1172	-0,0130	-0,0736	-0,001392	**0,03195**
16	0,035	0,573	0,609	0,0816	0,0490	0,1510	0,0326	-0,0694	-0,006718	**0,08228**
17	0,503	0,475	0,979	0,0529	0,0479	0,0748	0,0050	-0,0219	-0,006768	**0,12801**
18	0,074	0,554	0,629	0,0883	0,0593	0,1491	0,0290	-0,0608	0,001281	**0,01451**
19	0,419	0,126	0,546	0,0728	0,1110	0,3973	-0,0383	-0,3246	-0,023959	**0,32933**
20	0,585	0,461	1,047	0,0557	0,0442	0,0759	0,0115	-0,0202	-0,005236	**0,09401**
21	0,524	0,105	0,630	0,0683	0,0713	0,4156	-0,0030	-0,3474	-0,012934	**0,18945**
									-0,003902	**0,39418**

On average, the annual growth rates in output, labor and capital among sectors are positive and equal to 2.99%, 4.38%, and 4.11%, respectively. On the contrary, the average annual growth rates in productivity of labor and capital among sectors are, equal to -1.39%, and -1.12%, respectively. As far as the contribution of technology to economic growth is concerned, its average value among sectors is equal to 39%, which is slightly lower compared with the relative performance of other O.E.C.D. countries (O.E.C.D., 1996, p. 58).

Continuously, using these estimates as well as other relevant data the paper groups the various sectors of economic activity into sectors with similar technological and growth characteristics. Except for the estimates presented above, the human capital estimates come from Belegris-Robolis, Michaelides et Lapatsioras (2006).

The variables used are: the annual growth rates (%) of output (dY), labour (dL), capital (dK), labour productivity (dl), capital productivity (dk), Total Factor Productivity-T.F.P. (dA), human capital (dH) and technology's contribution to economic growth (π). Using *K*-means algorithm and the Euclidean distance we partition these variables into distinct clusters (see Table II).

Table II

Cluster Analysis Results for technology characteristics in Greece, by sector (1988-1998).

variable	Cluster 1 (1,2,3,4, 5,7,8,10,11)	Cluster 2 (6,9,12,13,14,15,16,17,18,20)	Cluster 3 (19,21)
π	75,56	9,58	25,94
dA	-0,30	-0,18	-1,84
dY	0,18	4,70	7,06
dH	2,15	2,40	-0,08
dL	3,03	4,34	9,12
dK	-7,90	7,65	40,65
l	-2,87	0,36	-2,07
k	8,07	-3,71	-33,60

Concentration on clusters' performance at the economy wide level hides interesting variations. For instance, the first cluster experiences a slightly negative annual rate of growth of T.F.P. which, given the very high contribution of technology in economic growth, has prevented the annual production growth rate from being high. This very low growth rate is mainly due to the dramatic capital shrinking and not to the increase in labor.

The second cluster experiences the lowest contribution of technology-driven economic growth. Thus, despite the slightly negative growth rate in TFP, the significant increases in labor, physical and human capital have led to a significant increase in production.

Finally, the third cluster presents a significant dependence upon technology, a negative change in TFP but a positive and significant growth rate in production, whereas the human capital remains practically unchanged. Meanwhile, it experiences an extremely high annual growth in capital and labor which have contributed to the cluster's significant growth rate.

At this point, we should stress the fact that all estimates are subject to a margin error and the production function estimate is obviously contingent on an estimate of the capital stock (Stikuts, 2003). In other words, the methodology we used is popular and appropriate, but it should be treated with caution since the parameters and the capital stock are estimated figures and, therefore, there is some uncertainty in their estimation. Obviously, such figures are estimates and not firm, precise measures.

5. Conclusion

In this paper we used the Growth Accounting methodology to estimate technological change, as well as labor and capital productivity in the various sectors of the Greek economy over the period 1988-1998. Continuously, we used the Clustering Analysis methodology to group the various sectors of economic activity in Greece based on their technological characteristics. The twenty-one sectors of economic activity were thus assembled into clusters presenting similar technology characteristics. The results showed that the technological level, as measured through annual growth in Total Factor Productivity, has remained practically unchanged. Meanwhile, technological change accounts for about 40% of economic growth, which is slightly lower compared with the relative performance of other O.E.C.D. countries. Finally, the various sectors of economic activity tended to form three (3) distinct clusters experiencing similar technological and growth characteristics within each cluster.

Given the fact that technology is critical for productivity and economic growth, the T.F.P. estimates are important policy variables. Thus, our investigation has direct relevance for policy issues for Greece. For instance, in case the Greek government wishes to support the weakest economic sectors, our analysis pinpoints the cluster of sectors, the performance of which is poor and needs enhancement. In such a case, the Greek government could choose the third cluster expressing the “service” sectors.

The implementation of a science and technology (S&T) policy should focus the effort on a carefully selected cluster. For instance, the first cluster seems to constitute a good choice since it demonstrates a high dependence upon technologically induced economic growth. In case this cluster could achieve a positive T.F.P. growth rate, the result would be satisfactory.

However, despite having implemented a successful program for stabilizing the macroeconomic environment, Greece is still in the process of developing an effective strategy for promoting technological progress. It has no well defined areas of comparative advantage in the international sphere, and it has no sector like the export–oriented electronics in Ireland that could serve as the driving force behind economic growth (Bosworth and Kollintzas, 2001). If the country is not going to use its tradable goods as the driving source for growth, it will need to develop an upgrading of domestic industries based on technological advancement and innovation.

Of course, in Greece certain characteristics of the S&T system, such as the small size of the research community, the dispersion of the research effort to multiple sectors and themes, the weak communication among laboratories, as well as between the research and production systems, seem to constitute a handicap to the dissemination of knowledge based information and, thus, to technology transfer.

No major reform has been introduced since 1985 concerning the legal framework whereas the national S&T policy has, traditionally, been supported by E.U. funds. Undoubtedly, international co-operation and E.U. programs consist an important channel of technology transfer to the country. Universities account for the great majority of absorption of the program funding, while industrial participation remains low. Evaluation of the efficiency of research projects should be integrated in the policy formulation. More precisely, the new programs should contribute to new technological activities generating competitive advantage, and assist research teams to commercialize the results. The programs have to motivate the business sectors in increasing their contribution to R&D expenditure (see Belegri-Roboli and Michaelides, 2005).

Finally, there should be a concentration of future funding on the most promising fields of science and technology, while a monitoring and evaluation procedure should lead to the most successful financial schemes having the greatest relevance to the specificities of the Greek S&T system. The restructuring and the expansion of the existing infrastructure should be carried out selectively on the basis of expert studies. We believe that the results of this study could be utilized for the feedback of the policy formulation procedure and could contribute to the efficient allocation of future funds.

Conclusively, we agree with the E.C. report suggesting that Greece should give high priority to taking measures to increase technology diffusion and stimulate technology financing (E.C., 2000, p. 31), given the incorporation of other countries in the European Union financial area. Although some European countries report increasing T.F.P., the lack of comparability in methodology and time period hampers multi-country analyses of technological change. We believe that more extended research on the subject would be of great interest, including the use of alternative clustering algorithms, as well as the incorporation of additional variables in the model. The measurement of technological change for other European countries and the formation of technology clusters is a good example for future investigation.

References

Aerts, M., Molenberghs, G. and L. Ryan, 2002, *Topics in Modelling of Clustered Data*, CRC Press.

Belegri-Roboli, A. and Michaelides, P., 2005, Measuring R&D Multipliers: The Case of Greece, *Journal of Technology Transfer,* Vol. 30, No. 3, pp. 327-332.

Bosworth, B. and Kollintzas, T., 2001, Economic Growth in Greece: Past Performance and Future Prospects, in (Eds.) Bryant, R., Garganas, N. and Tavlas, G., *Greece's Economic Performance and Prospects*, Bank of Greece and The Brooking Institution, Athens, pp. 189-237.

Dornbusch, R. and Fischer, S., 1993, *Macroeconomics,* Athens: Kritiki Publications (*in Greek*).

Denison, E., 1985, *Trends in American Economic Growth, 1929-1982*, Washington, D.C.: The Brookings Institution.

European Commission, 2000, *European Economy*, Directorate-General for Economic and Financial Affairs, 70.

Eurostat, 2000a, *Key Data on Vocational Training in the European Union, Office for the Official Publications of the European Communities*, Luxembourg.

Eurostat, 2000b, *Natural Resource Accounts and Environmental Input-Output Tables for Greece 1988-1998,* European Commission and Institute of Computer and Communications Systems of N.T.U.A., Luxembourg/Athens *(authored and edited in Greek by Dr. N. Mylonas)*.

Glascoe, L., Glaser, R., Hung-Neng S. Chin, and G. Loosmore, 2004, Regional-Scale Wind Field Classification Employing Cluster Analysis, *13th Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Session 7: Variability and Uncertainty*, 24 August 2004

Griliches, Z., 1988, 'Productivity Puzzles and R&D: Another Nonexplanation', *Journal of Economic Perspectives* 2, Fall, pp. 9-21.

Indian Statistical Institute, *Introduction to Clustering*, Documentation Research and Training Centre.

Jain K.and R. C. Dubes, 1988, *Algorithms for Data clustering*, Prentice Hall.

Jones, H., 1993, *Introduction to Contemporary theories of Economic Growth,* Athens: Kritiki Publications (*in Greek*).

Jorgenson, D., 1988, 'Productivity and Postwar U.S. Economic Growth', *Journal of Economic Perspectives* 2 (Fall), pp 23-41.

Kaufmann, L. and P.J. Rousseeuw, 1990, *Finding Groups in Data: An Introduction to Cluster Analysis*, John Wiley and Sons.

Mankiw, N. G., Romer, D. and Weil, D., 1992, 'A Contribution to the Empirics of Economic Growth', *The Quarterly Journal of Economics*, May, pp. 407-37.

Michaelides, P., Economakis, G., Milios, J., Maroudas, L. and Aggelis, V., 2004, Growth and Technological Change: A Contribution to the Investigation of Russia's Economic Process, *East-West Journal of Economics and Business*, Vol. VII, no 2, pp. 39-62.

National Statistical Service of Greece, National Accounts and other Statistical Data, Athens, *various years*

O.E.C.D., 1996, *Research and Development Expenditures in Industry: 1973-1993*, Paris.

O' Mahony, M., 1992, *Productivity in the EU, 1979-'99*, The Public Enquiry Unit, HM Treasury, London

Page, J., 1994, 'The East Asian Miracle: Four Lessons for Development Policy', *NBER Macroeconomics Annual 9,* pp. 219-269.

Romer, D., 1996, *Advanced Macroeconomics*, The McGraw Hill Companies.

Rosenberg, N., 1982, *Inside the Black Box: Technology and Economics*, Cambridge: Cambridge University Press.

Stewart, K., 2005, *Applied Econometrics*, Brooks/Cole, Thomson Inc.

Statsoft, 2004, *Clustering Analysis*, Electronic Textbook, StatSoft Inc.

Stikuts, D., 2003, "Measuring output gap in Latvia", *Working Paper 2/2003 - 22 S,* Riga: Latvijas Banka.

Solow, R., 1956, 'A Contribution to the Theory of Economic Growth', *Quarterly Journal of Economics*, LXX, pp. 65-94.

Solow, R., 1957, 'Technical Change and the Aggregate Production Function', *Review of Economics and Statistics*, 39, 3, pp. 312-320.

Tassey, G., 2004, 'Policy Issues for R&D Investment in a Knowledge-Based Economy', *Journal of Technology Transfer*, 29, pp. 153–185.

Thirlwall, A., 2001, *Growth and Development*, Athens: Papazissis Publications (*in Greek*).

Tryon, R.C., 1939, *Cluster Analysis*, Ann Arbor, MI, Edward Brothers.

Young, A., 1994, 'The Tyranny of Numbers: Confronting the Statistical Reality of the East Asian Growth Experience', *NBER Working Paper* No. 4680.

Appendix

Table III

Regression Results Cobb-Douglas Production Function for Greece by sector, 1988-1998.

Sector	lnA(t)	t-stat	a	t-stat	b	t-stat	R^2	S.E.	DW-stat
1	11,728	11,332	0,170	1,163	0,048	0,559	0,48	0,041	2,84
2	5,852	2,127	0,350	1,753	0,146	1,657	0,36	0,049	1,04
3	6,703	2,086	0,610	2,687	0,014	0,505	0,80	0,032	2,14
4	-7,047	-1,020	0,233	1,223	1,203	2,152	0,70	0,027	2,64
5	4,075	1,579	0,708	2,781	0,047	3,453	0,63	0,040	1,97
6	0,863	0,338	0,529	2,686	0,436	1,550	0,86	0,072	1,67
7	-6,646	-0,313	0,762	1,451	0,856	0,719	0,29	0,116	1,76
8	9,305	3,821	-0,37	-1,223	0,554	1,529	0,24	0,033	1,75
9	-13,258	-3,707	1,674	8,058	0,532	5,026	0,90	0,027	2,49
10	-2,946	-0,795	0,389	3,452	0,797	4,312	0,70	0,071	2,50
11	-0,635	-0,191	1,066	3,929	0,114	2,964	0,72	0,039	2,39
12	8,336	5,768	0,112	1,687	0,230	3,847	0,65	0,023	2,56
13	5,529	5,804	0,591	5,949	0,028	1,150	0,93	0,030	2,54
14	0,392	0,097	0,502	1,791	0,467	1,166	0,80	0,051	1,21
15	9,418	35,902	0,013	0,335	0,376	16,737	0,99	0,011	2,29
16	5,343	5,779	0,035	0,293	0,573	12,180	0,99	0,037	1,68
17	0,442	0,167	0,503	0,872	0,475	1,361	0,94	0,052	0,54
18	4,764	2,461	0,074	0,279	0,554	4,178	0,91	0,093	1,66
19	7,124	6,353	0,419	4,472	0,126	7,152	0,99	0,026	1,78
20	-0,757	-0,449	0,585	2,324	0,461	3,473	0,98	0,032	1,71
21	5,679	2,894	0,524	3,047	0,105	3,233	0,95	0,047	1,44

Table IV

Sector Classification

Sector	Description	I.S.I.C. rev.2
1	Agriculture, forestry and fishing	1
2	Mining	2
3	Food, Beverages and Tobacco	31
4	Textiles, apparel and leather	32
5	Wood products and furniture	33
6	Paper, paper products and printing	34
7	Petroleum and coal products	353+354
8	Industrial chemicals, Rubber and Plastic Products	351+352–3522+355+356
9	Non-metallic mineral products	36
10	Iron and steel, non-ferrous metals	371+372
11	Metal products	381
12	Shipbuilding and other transport, motor vehicles, aircraft, electrical apparatus, non electrical apparatus, professional goods, other manufacturing	382–3825+383+3832+3841+3842+3844+3849+3843+3845+385+39
13	Electricity, gas and water	4
14	Construction	5
15	Wholesale and retail trade	61
16	Hotels and restaurants	62
17	Transport, storage and communication	71+72
18	Finance and insurance	81
19	Real estate and business services	82
20	National defense and public administration	-
21	Communication, social and personal services	9