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Full Length Research Paper

Empirical analysis of technological innovation capacity and competitiveness in EU-15 countries

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This paper carries out an analysis of the existence and characteristics of technology innovation clusters in EU-15 countries, also studying if belonging to a group or cluster explains differences in competitiveness among countries. Based on the main Science and Technology Indicators 2009 published by Eurostat (European Commission, 2009a) in addition to competitiveness indicators used by the European Commission (2009b), the World Economic Forum (2009) and IMD (2008), an empirical study has been conducted- using a cluster analysis – about the technological innovation and competitiveness variables for each country during the period 1998 to 2008. The results indicate the existence of five distinct groups of countries characterized by different levels of technological innovation and competitiveness.

Key words: Technological innovation, competitiveness, cluster analysis, EU-15.

INTRODUCTION

Science and technology levels have been measured by Governments and researchers in industrialized countries for the last 50 years, but interest has been growing recently, due to the generally accepted belief that technology is a key explanatory variable for competetiveness, growth, productivity, job creation and wealth (Juma et al., 2001). Being able to measure a country's capacity for innovation has interest at the national level, as it is generally accepted that technological innovation is one of the main factors to achieve sustainable economic growth (Grupp, 1998; 2004).

According to Porter (1991), innovation, whether it relates to processes, products or organizations, determines the competitiveness of a nation, which depends ultimately on the companies' ability to innovate and improve.

All these theories have resulted in a variety of studies on the relationship between innovation and national competitiveness, such as Solow (1956), Soete (1981), Fagerberg (1987), Porter (1990), Calvert et al. (1996) and Griliches (1998); although these papers do not agree on a single theory on the relationship between innovation and competitiveness, they do clarify the determining factors of innovative conduct and its implications on national competitiveness.

During the last years, a number of empirical studies have attempted to measure different aspects of the technological capabilities and components that may have an influence on national competitiveness (Grupp and Mogee, 2004; Archibugui and Coco, 2005; IMD, 2009; WEF, 2009).

In addition, the concept of differences in technological capacity between countries as one of the major factors explaining the existence of country clusters is a hypothesis worth investigating for innovation researchers (Godinho et al., 2005). For that reason, throughout this work, the study endeavours to answer the question concerning the role of technological innovation capacity and competitiveness of the different countries in order to form clusters.

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Based on literature on national innovation capacity, economics of technological change and national competitiveness, the objective of this paper is to study the existence and features of technological innovation clusters in EU-15 countries, analyzing if belonging to a group or cluster helps explaining the differences in competitiveness among these economies. For that purpose, a cluster analysis has been conducted to gather the countries of EU-15 within groups of homogeneous behaviour, according to selected variables of technological innovation and competitiveness. This grouping of countries, based on their degree of similarity, can contribute to a better appreciation and evaluation of innovative activity in each case.

COMPETITIVENESS

The concept of competitiveness can be analyzed from different levels: firm, industry or sector, and nation (Industry Canada, 1995). In this paper, the focus was on national competitiveness and its relationship with the technological innovation levels of the different countries.

There is a widespread acceptance of the importance of competitiveness, although different definitions still stand. National competitiveness has historically been associated to some macroeconomic variables, like the exchange rates, prices or export shares and there is a generalized notion that the competitiveness of a country is related to its participation in world markets (Solleiro and Castañón, 2005). This approach implies a zero-sum game, as one country's gain come at the expense of others (World Economic Forum, 2006) and has been criticized by several authors who consider that other aspects should also be taken into account.

The definition of national competitiveness has lately evolved to a more complex concept that includes both macroeconomic and microeconomic factors. Some authors (Scott, 1985; Storper, 1997) include references to income and standard of living in their definitions of competitiveness. Porter (1990) argues that competitiveness is strongly linked with productivity and the standard of living of a country, and shows that pure macroeconomic variables are not sufficient to explain the welfare of a country: for example, in 1970s and 1980s, several countries achieved high levels of welfare while suffering macroeconomic problems (Japan had a strong budget deficit, Korea and Italy, both with high interest rates, or Germany and Switzerland, that suffered strong currency appreciation). According to Porter (1990), competitiveness is determined by the productivity with which a nation utilizes its human, capital, and natural resources to produce goods and services. Competitiveness thus depends on the microeconomic capability of the economy explained by the sophistication of the companies and the quality of the national business environment.

Different efforts have been made to evaluate and measure the competitiveness of the countries. There are two exhaustive and acknowledged studies on competitiveness: the Competitiveness Yearbook, elaborated by the International Institute for Management Development and the Global Competitiveness Report, published by the World Economic Forum. Both institutions analyze the many factors enabling national economies to achieve long-term prosperity and competitiveness including different macroeconomic and microeconomic variables that determine the level of productivity of a country. These two international organizations propose the following definitions of competitiveness:

i. The International Institute for Management Development (IMD) defines competitiveness as "the capacity of a country or a company to create greater prosperity than its competitors in international markets" (IMD, 2010).
ii. The World Economic Forum (WEF) defines competitiveness as the "group of institutions, policies and factors that determine the level of productivity of a given country" (WEF, 2009).

The study also considered European Innovation Scoreboard (EIS), as an initiative of the European Commission to evaluate and compare the innovation results of the European Union country members.

TECHNOLOGY INNOVATION CAPACITY

The concept of technological capacity has been studied by numerous authors. Although the concept was initially used for company analysis, it has also been applied to industries and countries. Lall (1992) emphasized three aspects defining the "national technological capacity" as: 1) The ability to gather the financial resources needed and their efficient use; 2) Abilities, including not only general education, but also technical and managerial specialization; and 3) What the author called "national technological effort", associated to measures such as investment in R+D, patents and technical staff (Fagerberg, 2008). This implies that both company specific factors and national factors (incentives, institutional structure, resource allocation, human capital and technological effort) are important in the generation of technological capabilities. Thus, it is possible to identify the accumulation of technological capabilities both at microeconomic level (in companies) and at national or macroeconomic level. Therefore, the production of indicators of technological innovation capabilities has recently developed and grown, both at micro and macro levels. In fact, data collections and surveys are carried out systematically at the enterprise, industry, technology and country level (Sirilli, 1997; Smith, 2005).

To make the selection of indicators, the study took into account some previous studies that will be further discussed in this paper, and it relied on the conceptual framework of national innovation capacity, defined as the ability of a country as a political and economic entity, to produce and commercialize in the long-term, a flow of "new technologies to the world" (Furman et al., 2002). The main purpose of the indicators is to compare different countries' positions and their changes. At this point, Archibugui et al. (2009) raises two interesting methodological issues. The first issue relates to the use of "countries" as the unit of analysis, because countries are composed of different areas and regions that can be heterogeneous. In this regard, the ability to make comparisons between countries is based on the assumption that a national innovation system is able to distribute knowledge throughout the country (Patel and Pavitt, 1995). On the other hand, a second question that may arise is the usefulness of international comparisons, since differences in technological capabilities can be very large between certain countries, and comparisons might have more meaning if they are made between similar national innovations systems, this being one of the reasons that led us to focus our research in EU-15.

DEFINITION AND RATIONALE OF THE INDICATORS USED IN THE EMPIRICAL ANALYSIS

The study will now describe the indicators to be used as dimensions and variables in the empirical analysis of this work. They correspond to the main Science and Technology Indicators 2009 published by Eurostat (Europaen Commission, 2009a) in addition to competitiveness indicators used by the European Commission (European Commission, 2009b), the World Economic Forum (World Economic Forum, 2009) and the International Institute for Management Development (IMD, 2008) (Table 1).

'Dimensions' are defined as sections in which variables are grouped according to their scope of information. They are:

i. Research and development.
ii. High technology industries and knowledge-intensive services.
iii. Patents.
iv. Human resources in science and technology.
v. Competitiveness.

Research and development

Research and development (R&D) activities are considered the main vehicle for development, innovation, and economic growth. The basic measure is expenditure on R&D activities made by a statistical unit or a sector of the economy over time (European Commission, 2009a). The variables used as an indicator for the R&D dimension in this study are:

i. Total R&D expenditure as a percentage of GDP.
ii. Total R&D expenditure by source of funds: enterprises, percentage of total.
iii. Total R&D expenditure by source of funds: public sector, percentage of total.
iv. Total number of researchers.
v. Staff employed on R&D as a percentage of the labour force.
vi. Share of women in research as percentage of total researchers.
vii. Share of government budget for R&D as a percentage of total general government expenditure.

High technology industries and knowledge-intensive services

In industrialized countries, the creation, development, and commercialization of new technologies are an imperative to remain competitive. High-tech sectors are essential to economic growth, productivity and welfare, and are generally a source of high value-added and well-paid, employment. Therefore, technology-intensive firms are vital in ensuring the competitiveness of nations (European Commission, 2009a). The variables used to describe this dimension are:

i. Exports of high technology products as a share of total exports.
ii. Employment in high and medium-high technology manufacturing sectors as a share of total employment.
iii. Employment in knowledge-intensive services sectors as a share of total employment.

Patents

Patents are documents that represent technical inventions that have been passed by a patent office, both to ensure its novelty and to clarify its potential usefulness, and therefore, are an important source of information for technological development (European Commission, 2009a). Variables chosen as representative of the patents dimension are:

i. Patent applications to the European Patent Office (EPO) as number of applications per million inhabitants.
ii. Total European patent applications: EPO and Patent Cooperation Treaty as number of applications per country.
iii. European patents in high technology as number of patents per million inhabitants.
iv. Patents granted by the United States Patent and Trademark Office (USPTO) as number of patents per million inhabitants.

Human resources in science and technology

The indicators on human resources in science and

Table 1. Selection of dimensions and variables.

Dimension	Variable	Definition
Research and development	01. % Tot. Exp. R&D	Total expenditure on R&D (% GDP)
	02. % Tot. Exp. Bus.	Total R&D expenditure by source of funds: enterprises, percentage of total expenditure on R&D
	03. %Tot. Exp. Pub	Total R&D expenditure by source of funds: public sector, percentage of total expenditure on R&D
	04. Tot Research	Total number of researchers
	05. % Emp. R&D	Staff employed on R&D as a percentage of the labour force
	06. % Women	Percentage of women in research (% of total researchers)
	07. % Gov. Budg.	Government budget for R&D (% general government expenditure)
High technology and knowledge intensive services	08. % Exp Tec	Exports of high technology products (% of total exports)
	09. % Empl Tec	Employment in high and medium-high technology manufacturing sectors (% of total employment)
	10. %Empl Know	Employment in knowledge intensive services (% of total employment)
Patents	11. EPO	Patent applications to the European Patent Office (number of applications per million inhabitants)
	12. Tot Pat	Total European patent applications: EPO and Patent Cooperation Treaty (number of applications per country)
	13. Pat Tec	European patents in high technology (number of applications per million inhabitants)
	14. USPTO	Patents granted by the United States Patent and Trademark Office (USPTO) (number of patents per million inhabitants)
Human resources in science and technology	15. %HRST	Human resources in science and technology (% of total labour force)
Competitiveness	16. EIS	European Innovation Scoreboard, innovation performance indicator
	17. GCI	Global Competitiveness Index , competitiveness index
	18. IMD	Institute for Management and Development, competitiveness index

Source: Elaboration from European Commission (2009a, 2009b); WEF (2009); IMD (2008).

technology contribute significantly to measure the new knowledge-based economy and to review the demand and supply of highly qualified personnel in science and technology (European Commission, 2009a).

The study uses a single variable to describe the human resources in the science and technology dimension: Human resources in science and technology as a percentage of the total labour force.

Competitiveness

Differences in competitiveness among the groups of countries in the EU-15 will be analyzed through the data provided by the following indicators:

i. European Innovation Scoreboard (EIS): It is based on analysis of statistics published by Eurostat and data published by other international sources (European Commission, 2009b).

ii. Global Competitiveness Index (GCI): Is the main indicator of competitiveness used by the WEF (World Economic Forum). This index considers several components, each capturing a different aspect of the complex concept of competitiveness. The information is grouped in three blocks: Basic requirements, Efficiency enhancers and Innovation factors (World Economic Forum, 2009).

iii. International Institute for Management and Development (IMD): This Swiss institution publishes the World Competitiveness Ranking in collaboration with the University of Chile School Of Business. It focuses on four major factors that shape the competitive environment of an economy; Economic performance, Government efficiency by promoting competition, Business efficiency and infrastructure (IMD, 2008).

From these indicators, the study chooses a set of variables representing the dimension of 'competitiveness' (Table 1). These 18 defined variables constitute the whole range of ordered data that will be analyzed to reveal the distribution of the technological innovation capacity and competitiveness in the EU-15 and to measure the differences among those countries in the period 1998 to 2008.

With regards to innovation variables, the reasons for this selection of indicators were as follows:

i) From a purely conceptual point of view, the study has followed the path marked by previous studies (World Economic Forum, 2009; Archibugui and Coco, 2004a, b; UNDP, 2001) which argue that these variables represent different aspects of the cumulative national technological process, called the innovation capacity of a nation (for example, patents) (Castellacci and Archibugi, 2008).
ii) The availability of abundant and reliable data for the countries studied in the 1998 to 2008 period is decisive.
iii) The choice of these indicators allows simultaneous consideration of input and output measures, and thus, enables a more comprehensive study of the importance and effectiveness of R&D. This is especially appro-priate because input measures mainly consider the effort devoted to R&D, but output measures focus on the effectiveness of those measures to produce new knowledge (Sancho, 2002).
iv) The indicators has the advantage of providing a more precise categorization of the positions of the countries than using a single, indirect indicator.

METHODOLOGY

The methodology used for the empirical analysis, whose objective is to analyze the existence and characteristics of technology innovation clusters in EU 15 countries is presented, and also, if belonging to a group of cluster helps to explain the differences in competitiveness among these economies is assessed.

For that purpose, the study first calculates the average values for each of the variables earlier described, during the period 1998 to 2008 for every country in the EU-15. The countries included are: Germany (DE), Austria (AT), Belgium (BE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Greece (EL), Netherlands (NL), Ireland (IE) Italy (IT), Luxembourg (LU), Portugal (PT), United Kingdom (UK) and Sweden (SE).

Secondly, groups are identified through a cluster analysis, applying the hierarchical algorithm of the minimum variance or Ward Method (forming clusters by minimizing the sum of squares) to the standardized values of the variables. The cluster analysis is widely used in this type of studies (Mehra, 1996; Nath and Gruca, 1997; Veliyath and Ferris, 1997; Short et al., 2002; López and Vázquez, 2007; Castellaci and Archibugi, 2008; European Commission, 2009b).

The main criticism made of cluster analysis is that it considers, a priori, the existence of homogeneous groups or clusters. To determine the number of clusters to be formed, the present work has applied two constraints which are used as standards in this type of investigations (Harrigan, 1985; Lewis and Thomas, 1990; Fiegenbaum and Thomas, 1990). These two restrictions are: 1) groups observed must explain, at least, 65% of the total variance; and 2) adding another group means an improvement in total adjustment of, at least, 5%.

At this point, trials are conducted. Table 2 shows the results obtained in terms of both restraints, for four, five and six clusters. Obviously, the three variables in the competitive dimension are excluded from the analysis, since the competitiveness dimension is precisely the one to be contrasted. It can be seen how the number of clusters formed is five.

The next and final step in the empirical process is to validate the cluster structure. For that purpose, the study must determine if there are significant differences between the groups obtained. This is achieved through the p-value of the F test, resulting from an ANOVA analysis, which examines the individual variance for each of the variables. It can be stated that there is a statistically significant difference (with a confidence level of 95%) between the average values of each variable in each cluster, if the p-value of the F test is below 0.05. Table 3 summarizes the results for the case of five clusters.

Analyzing the results of p-value of the ANOVA F test, the study observes that all variables except one are significant, as the contrast F is below 0.05. The exception variable corresponds to the percentage of women researchers. Table 4 summarizes the results obtained in the above table for the variables of competitiveness. Consequently, results confirm that differences in technological innovation and competitiveness among the clusters are significant.

ANALYSES OF RESULTS

The countries that form the five groups have been defined as: 1) Leaders (in technological innovation); 2) Followers (in technological innovation); 3) Mediterranean; 4) Moderate; and 5) Germany, being classified as shown in Table 5.

Table 6 presents the averages of 18 selected variables for each group, and the average of the total sample of 15 countries as a whole. At the end of the table, the variable, Total Population, shows the average of the total population for each group in December 2008, and is useful to analyze the variables, Total Number of Researchers, and European Patent Applications, when measured in absolute terms.

The major characteristics of each of the five clusters obtained, based on the analysis of the data presented in Table 6, are discussed further.

Leaders

This group consists of Finland and Sweden. The different variables are analyzed now, and it can be observed how these two Scandinavian countries are at the forefront of the group in most of them and it is the reason to designate them as leaders. Beginning with the first dimension, the leaders are the ones that increased more on their expenditure on R&D in relation to GDP, with 3.56%, which means 88% above average; those with the highest percentage of staff employees on R&D with 1.85 and 58% above average; and within that staff, they have the highest percentage of women with 39.25%, which is also above average by 29%. In addition, the weight of the government budget for R&D is the highest of the five groups, with 1.75 and 24% above average. Therefore, it can be observed that in the dimension of research and development, the leaders obtain the best results of the five groups in four variables, indicating the importance that these countries place on that dimension.

Table 2. Variance adjustment.

Variable	4 Clusters	5 Clusters	6 Clusters
01. % Tot. Exp. R&D	89.99	88.78	88.90
02. % Tot. Exp. Bus.	56.27	79.61	74.72
03. %Tot. Exp. Pub	65.84	78.63	73.65
04. Tot Research	35.43	32.46	53.05
05. % Emp. R&D	59.82	85.71	84.10
06. % Women	43.69	42.11	44.07
07. % Gov. Budg	0.00	17.38	6.18
08. % Exp Tec	45.63	45.10	78.12
09. % Empl Tec	43.04	68.72	62.76
10. % Empl Know	77.50	73.73	67.74
11. EPO	82.09	81.58	89.89
12. Tot Pat	86.78	85.92	86.29
13. Pat Tec	77.30	74.92	73.55
14. USPTO	93.63	93.93	95.30
15. %HRST	67.52	61.51	59.48
Average	61.64	67.34	69.19
% Variation	18.11	9.25	2.74

Source: Own preparation.

Table 3. Descriptive statistics of clusters (average and standard deviation) and test ANOVA for 5 clusters.

Variable	C1(n=2)	C2 (n=6)	C3 (n=4)	C4 (n=2)	C5 (n=1)	F ANOVA	p-value
01. % Tot. Exp. R&D	3.56	2.04	0.91	1.42	2.48	40.04	0.0000
	0.25	0.26	0.23	0.29	0.00		
02. % Tot. Exp. Bus	67.40	52.54	37.58	71.10	66.16	7.75	0.0041
	1.44	7.24	8.47	14.99	0.00		
03. %Tot. Exp. Pub	54.92	31.91	48.59	20.64	30.68	7.85	0.0039
	1.49	5.78	7.66	10.20	0.00		
04. Tot Research	64.987	130.803	84.747	9.794	413.721	2.69	0.0429
	18.125	141.303	64.497	10.581	0		
05. % Emp. R&D	1.85	1.20	0.66	1.45	1.20	4.35	0.0270
	0.36	0.15	0.12	0.96	0.00		
06. % Women	39.25	27.04	36.40	25.09	21.33	2.38	0.1214
	12.84	6.39	5.91	7.66	0.00		
07. % Gov. Budg.	1.75	1.48	1.35	0.89	1.69	1.59	0.0025
	0.39	0.21	0.55	0.31	0.00		
08. % Exp. Tec.	17.71	17.31	6.59	31.23	15.02	7.97	0.0037
	3.95	6.74	0.72	4.21	0.00		
09. % Empl. Tec.	7.18	6.04	4.55	3.90	10.98	3.26	0.0492
	0.16	1.06	2.29	3.57	0.00		

Table 3. Contd.

10. %Empl. Know	43.08 4.94	38.04 4.74	24.78 3.15	36.35 4.38	32.42 0.00	8.23	0.0033
11. EPO	251.25 3.60	150.133 42.62	28.64 32.00	127.60 95.18	271.14 0.00	10.87	0.0012
12. Tot Pat	1.752 0.609	3.334 2.727	1.338 1.971	0.159 0.105	22.043 0	19.86	0.0001
13. Pat Tec.	2.64 35.77	32.33 13.60	3.20 2.90	14.64 0.83	39.71 0.00	10.10	0.0015
14. USPTO	51.49 12.42	70.51 11.82	10.66 13.37	67.85 32.44	132.55 0.00	32.03	0.0000
15. %HRST	46.60 1.22	41.65 5.01	28.61 6.91	38.77 2.18	42.45 0.00	5.44	0.0137
16. EIS	0.63 0.04	0.53 0.04	0.37 0.01	0.53 0.01	0.58 0.00	24.67	0.0000
17. GCI	5.52 0.02	5.31 0.16	4.41 0.25	4.92 0.10	5.46 0.00	20.28	0.0001
18. IMD	78.75 5.25	74.34 6.86	51.97 4.96	81.03 4.79	74.74 0.00	12.74	0.0006

Source: Own preparation.

Table 4. ANOVA results for the variables of competitiveness.

Variable	F ANOVA	p-value
EIS	24.67	0.0000
GCI	20.28	0.0001
IMD	12.74	0.0006

Source: Own preparation.

Table 5. Clusters.

Leader	Follower	Mediterranean	Moderate	Germany
Finland	Austria	Spain	Ireland	Germany
Sweden	Belgium	Greece	Luxemburg	
	Denmark	Italy		
	France	Portugal		
	The Netherlands			
	United Kingdom			

Source: Own preparation.

On the second dimension, the variables of exports of high technology products and employment in high tech sectors, the leaders are in the second position and slightly above average whilst with respect to the variable

Table 6. Summary of the analysis for 5 cluster.

Cluster	01 %Tot. Exp. R&D	02 %Tot. Exp. Bus	03 %Tot. Exp. Pub	04 Tot Research	05 %Emp. R&D	06 %Women	07 % Gov. Budg.	08 % Exp. Tec.	09 % Empl. Tec.
1	3.56	67.40	24.92	64,987	1.85	39.25	1.75	17.71	7.18
2	2.04	52.54	31.91	130,803	1.20	27.04	1.48	17.31	6.04
3	0.91	37.58	48.59	84,747	0.66	36.40	1.35	6.59	4.55
4	1.42	71.10	20.64	9,794	1.45	25.09	0.89	31.23	3.90
5	2.48	66.16	30.68	413,721	1.20	21.33	1.69	15.02	10.98
Total	1.89	53.91	33.84	112,473	1.17	30.52	1.41	16.20	5.84

Cluster	10 % Empl Know	11 EPO	12 Tot Pat	13 Pat Tec.	14 USPTO	15 % HRST	16 EIS	17 GCI	18 IMD	Tot. Pop.
1	43.08	251.25	1,752	82.64	151.49	46.60	0.63	5.52	78.75	7,241,706
2	38.04	150.13	3,334	32.33	70.51	41.65	0.53	5.31	74.34	22,111,033
3	24.78	28.64	1,338	3.20	10.66	28.61	0.37	4.41	51.97	31,683,477
4	36.35	127.60	0,159	14.64	67.85	38.77	0.53	4.92	81.03	2,442,567
5	32.42	271.14	22,043	39.71	132.55	42.45	0.58	5.46	74.74	82,217,837
Total	34.58	136.28	3,415	29.40	69.13	38.50	0.50	5.06	69.88	26,289,938

Source: Own preparation.

employment in knowledge-intensive services they are inthe lead, with 43.08 and 24.58 % above average.

Looking at the third dimension, the study noted that the total number of European patent applications (a variable measured in absolute terms) is well below the European average and that of other groups; this result is obvious, as this group is formed only with small populations. However, if the other three variables were looked at, (measured in relative terms) related to patents, their results are above average and in particular, in European patents in high technology (82.64) and USPTO (151.49), they obtain values of 181 and 119% respectively, higher than the average for the EU-15. With regard to human resources in science and technology (46.60), they obtain the highest rate, as expected, 21% above average.

Finally, in the dimension of competitiveness, they perform well above the other groups of countries in the EIS indicator, with 0.63 and 26% above average, in the variable, GCI, reaching 5.52, occupying the first position and in the IMD indicator, the leaders are located in second position and, better than the average of EU 15.

Followers

This group is formed by: Austria, Belgium, Denmark, France, Netherlands and the United Kingdom. Countries in this group follow the results for the group leaders and Germany, both at the forefront of innovation, as shown by most of the 18 variables, and thus, the name of the conglomerate.

Looking in detail at the different variables, it was seen that this is consistently the case, except in two of them, (measured in absolute terms), because of population and size reasons: total number of researchers and total number of European patent applications. In fact, in these two cases, with figures of 130,803 and 3,334 respectively, this group would be in first place if not for Germany, whose case represents a separate cluster because of its special characteristics and will be studied later.

Examining the first dimension, research and development, it is noted that while the followers are not positioned first in any of their variables, they are in second or third place in most cases, and always around the average values. Regarding the second, third and fourth dimensions, high technology and knowledge intensive services, patents and human resources in science and technology, the same can be said.

Finally, analyzing the results for the three variables within the dimension of competitiveness, followers are always behind the group leaders and Germany, but above the average of the results for the EU 15.

Mediterranean

This group includes Spain, Greece, Italy and Portugal. In general, these are the countries with poorer outcomes, with the exception of the two variables measured in absolute terms, because they are countries with a relatively high number of inhabitants. It is noted how in some of the variables. They are not placed in last place, as is the general trend (for example, in the percentage of women researchers, with a 36.40%, they fall in second place behind the leaders and a 19% higher than the average).

In the variables government budget for R&D and knowledge-intensive services, this is also the case, and with figures of 1.35 and 4.55%, they do not occupy the last position of the five groups.

It should be noted that they occupy the first place in percentage of total expenditure on R&D financed by the public sector, with 48.59%, which represents a figure, 44% higher than other European countries; other groups get much higher percentages of R&D expenditure financed by the business sector, unlike the Mediterranean's last place with a 37.58 and 30% below the average for the EU-15. This reflects the greater weight of the Administration in the Mediterranean group as opposed to other groups where the business sector prevails.

As a conclusion withdrawn from the analysis from the dimension of competitiveness, the Mediterranean countries perform the worst results for the five groups defined herein

Moderate

This group is made up of Ireland and Luxembourg. It shows an irregular behaviour of its variables, that is, while some of them are very well positioned, other variables are relegated to backward positions, and this is why they have been named moderates. The most relevant variables in this group are discussed further.

The percentage of R&D expenditure, financed by the business sector is the highest of the five groups with a 71.10 and 32% above average. By contrast, the percentage of R&D expenditure financed by the public sector is the lowest at 20.64 and 39% below average. Accordingly, the percentage of government budget for R&D is the lowest of the five groups with a 0.89 and 37% below the average. These results contrast with those obtained in the Mediterranean group where the opposite occurred.

The total number of researchers and total number of European patent applications, with 9,794 and 0,159, respectively, is the lowest once again, due to the total number of inhabitants in each country. It is remarkable that the variable export of high technology products is 31.23%, which almost doubles the industry average. However, the percentage of employment in high-tech sectors is in last place with 3.90%.

Finally, with regards to the dimension of competitiveness, GCI and EIS show results above average, but it should be emphasized that they obtain the best result of the five groups in IMD, with 81.03.

Germany

It constitutes a cluster by itself due to a number of unique features. It is not unusual to get one or several clusters composed of a single individual from a sample population, and Porter (1980) advises of the validity of a situation such as the one presented here.

Germany is a country which includes cluster features in itself, and that overall, for most of the variables, is very well positioned and above the average for the EU-15.

Through innovation, in strategic planning and manufacturing processes in the last 20 years, Germany has achieved an increase of 100% of GDP with a reduced consumption of basic energetic resources of 27%. This has enabled the country to obtain a strategic advantage which, in turn, has encouraged others to follow the path of innovation and operational efficiency and has led to the creation of innovation clusters along the way (Federal Ministry of Economics and Technology, 2009; the International CHP / DHC Collaborative, 2009).

It performs well above the others in total number of researchers and total number of European patent applications with 413,721 and 22,043, respectively, partly due to being the country with the largest population surveyed, over 82 million inhabitants, but also to its innovation capacity. Thus, it leads in the following variables: employments in high-tech sectors with 10.98% ahead of the other groups and almost doubling the average; with regards to patents, the EPO variable (271.14) also occupies the first position, doubling the average. These results show Germany strength in the dimensions of high technology and knowledge-intensive services and patents, where the difference from the rest of the groups is remarkable. Similarly, the EIS, GCI and IMD variables are above the average.

Finally, analyzing the different features of each group, the dendrogram in Figure 1 shows the grouping of the

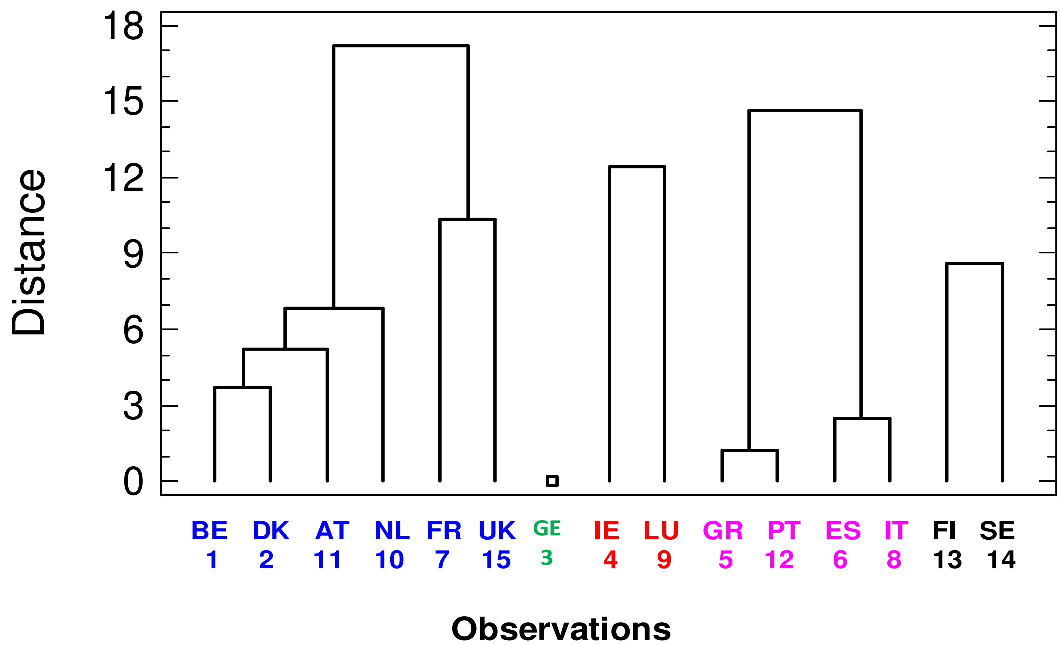

Figure 1. Dendrogram (Source: Authors' preparation).
BE, Begium; DK, Denmark; AT, Austria; NL, Netherlands; FR, France; UK, United Kingdom; DE, Germany; IE, Ireland; LU, Luxemburg; GR, Greec; PT, Portugal; ES, Spain; IT, Italy; FI, Finland; SE, Sweden

different countries within each cluster, reflecting the composition of the clusters and the distance among them. This figure summarizes the grouping process for the cluster analysis and indicates how similar objects connect with each other through linkages whose position in the diagram is determined by their level of similarity/ dissimilarity.

The horizontal axis represents the observations (countries) and the vertical axis shows the distance, lower values indicating higher similarity among observations and higher values indicating minimum similarity. Table 7 shows the grouping of the observations: the observations which are closer to each other (distance closer to zero) belong to Greece and Portugal (1.21422), followed by Spain and Italy (2.46602), they all form the clusters of Mediterranean countries.

Most distant observations (farther from zero) belong to Belgium and France (17.2306); these observations group with Denmark, Austria and Netherlands in the first case and with the United Kingdom in the second case, they all belong to the Followers cluster. The cluster formed only by Germany is represented by a dot in the dendogram with distance equal to zero.

In summary, the Mediterranean cluster shows the highest homogeneity among variables, whereas, the cluster with higher heterogeneity is the Followers group, due to its larger size (6 countries). Once the five clusters have been analysed, it is interesting to review Figure 2.

The study can observe that the 15 countries form homogeneous groups, countries of the group leaders and Germany being located in the upper right of the diagram, correspond with the highest values of these three variables (IMD, GCI, EIS), that is, being the most competitive.

In contrast, the group of Mediterranean countries are at the bottom left of the diagram, where the values of the three competitive variables are lower. The countries in the Followers group are located just to the left to the Leaders and Germany, "following" them, as indicated earlier. And finally, the study finds the two "moderate" countries around the centre of the diagram, as expected in a moderate or intermediate position. The message that emerges from this graph is the groupings of countries in these clusters based on the three variables of competitiveness: EIS, GCI and IMD, showing the direct relationship between the most technological innovative countries and their levels of competitiveness.

Conclusions

The present study presents an empirical analysis for classifying countries in the EU-15 into clusters which show a homogeneous competitive and innovative behaviour. Competitiveness differences among clusters and the countries included therein are explained through topological analysis of each group.

To this end, the study used 18 variables related to the

Table 7. Agglomeration schedule.

Stage	Clusters combined		Coefficient	Stage first appears		Next stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	12	1.21422	0	0	9
2	6	8	2.46602	0	0	9
3	1	2	3.71929	0	0	4
4	1	11	5.23726	3	0	5
5	1	10	6.85712	4	0	10
6	13	14	8.5949	0	0	0
7	7	15	10.3587	0	0	10
8	4	9	12.4339	0	0	0
9	5	6	14.6805	1	2	0
10	1	7	17.2306	5	7	0

Clustering method: Ward's; Distance Metric: Euclidean (source: own preparation).

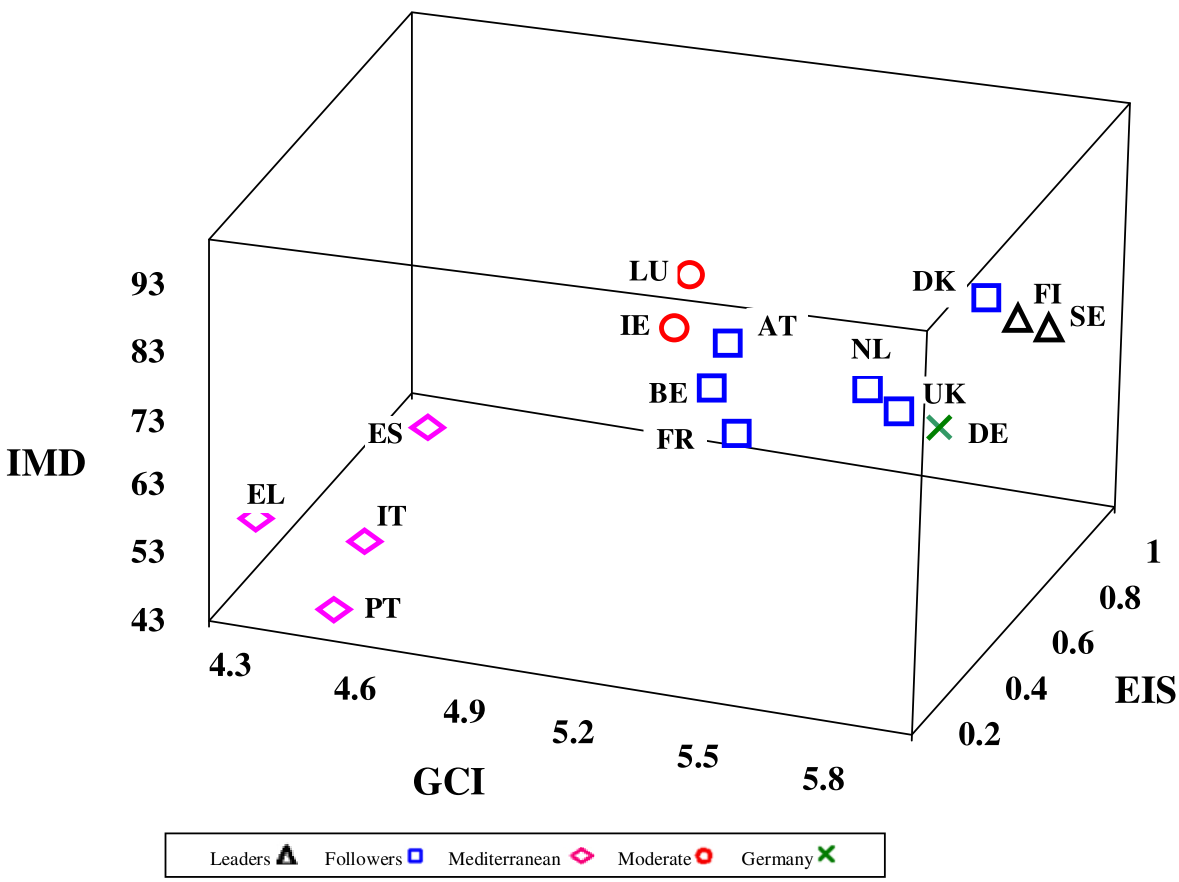

Figure 2. Competitiveness diagram (source: own preparation).

technological innovation capacity and competitiveness for the period 1998 to 2008. Through a widely used statistical system, - cluster analysis - the study examined the characteristics of the groups obtained. The usefulness of this methodology lies in being able to analyze the competitive structure of the EU-15, treating these groups of countries as one entity and facilitating the study and definition of convergence strategies.

The results reveal the existence of five distinct clusters characterized by different levels of technological innovation and competitiveness that the study has named: Leaders, Followers, Mediterranean, Moderate and

Germany. It can also be observed that countries grouped into clusters that perform better in technological innovation capacity in each of the analyzed variables, lead to higher levels of competitiveness for these countries, measured through the variables: EIS, GCI and IMD. As regards the theoretical interpretation of the empirical findings and their implications, first and foremost, from the perspective of the literature on innovation, it can be said that the results provide new evidence of the existence of five different clusters of countries grouped according to variables related to competitiveness and innovation capacity. Secondly, it seems clear that differences between countries are well reflected by the cluster analysis.

The study encourages the opening of new lines of research. In this regard, it poses the following questions:

i. How have countries changed from clusters during the period studied?
ii. How many of the countries who directed their efforts to jump to a higher group succeeded?
iii. Did any of these countries not just remain within their cluster, but fell to a lower cluster?

From the basis of this study, further investigation, for which a year on year analysis would be invaluable, was recommended.

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