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Patents as Indicators of Technological Innovation in Greece: Analysis for a Period of 25 Years

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This paper examines the development of technological innovation in Greece based on patent data for a period of 25 years (1988-2012). The analysis shows that technological innovation is dispersed among the eight broad technology sectors. Technological innovation is concentrated in certain fields of 'human necessities' ('medical preparations', the 'agricultural sector', 'basic and consumer goods'), 'elements of transporting and package', 'machinery' and different as well as complementary technologies related to 'building and construction'. This is the Greek pattern but also the dominant pattern of other countries, like Denmark, Hungary, Poland, Portugal, and Slovakia (based on their patents grants at the U.S.A. patent office) with the exception of 'fixed constructions'. On the contrary, different patenting trends can be recorded in Germany and France, where technological innovation is mainly concentrated in 'performing operations-transporting', 'electricity' and 'physics'. Comparing to other countries Greece is both characterized by an unusually large share of patents related to 'fixed constructions' and an insufficiency in 'chemistry-metallurgy', 'physics' and 'electricity'. This paper may have some implications for government policy. Greece is a country with very severe fiscal and structural problems. Whatever Greek government does, it is necessary to 'build' a new development agenda and policy and innovation plays a central role in this procedure. The existing pattern shows that technological innovations in the sectors of drugs-sanitary products, the agricultural and the construction industry are the most important. Therefore, it could be argued that only innovations related to the agricultural and construction industry could be a viable and technological direction. Thus, and in accordance with the paper results Greek innovation should focus on ecological building, sustainable forms of cultivations and energy.

JEL Codes: O31, O34 and O52

1. Introduction

Innovation has become a very important factor to corporate success, technological leadership and economic development, both at national and regional level (Buswell 1987, Malecki 1991). Schumpeter (1934), with his "gales of creative destruction", gave a vivid description of the effects of the introduction and diffusion of major technological discoveries and inventions in industry and the world economy and Romer (1994) emphasized the role of innovation. As a production factor innovation affects growth and contributes to the development of nations. According to Porter (1990) 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.

Since the pioneering study on the nature of innovation in the 1970s (Gibbons and Johnston 1974, Freeman 1974), many research works have been presented regarding innovation analysis. Innovation is the output of innovation process.

Innovation process is considered to be a highly systemic and complex process, which varies across industry, technology and firm size. Particularly for firms, firms develop

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innovations responding to their particular markets and technological challenges. All these factors make innovation difficult to be measured in complete and standardized ways. However, given the importance of innovation for national and firm wealth and welfare, the issue of measurement has become even more demanding. Nowadays, the literature on measurement of innovation is abundant, every day being improved and increased, and focused on measuring innovation at both firm, sector, regional and national level, as well as in combination to other economic and managerial parameters. The main methodological conclusion that can be derived from the study of literature is that innovation can be measured only through its products and only indirectly, with the contribution of relative indicators. One very important category of such indicators is patent indicators.

The objective of this paper is to study technological innovation in Greece, through the examination of patent records. Two points have to be noted: First, It is of particular importance, when examining a country's technological activities and identifying new trends, to highlight major technology fields, locate fields of dynamism and indicate fields for further development and specialization. Second, the reference to the historical evolution or long-tern perspective is necessary or even inevitable for such an analysis. Therefore, this paper uses data taken from the Greek granted patents since the establishment of the Greek Patent Office (1988), to study the Greek production of technological innovation, aiming at providing a deep understanding of the existing situation and an objective statistic reference for future research in this field. This research is original and the first attempt to study technological innovation based on patent records. Thus, research findings can't be compared with those of previous studies. In this context, the paper is structured as follows: Section two discusses the theoretical and empirical framework of innovation and technological development in relation to patent records and the construction of relevant indicators. Section three describes the data that has been used and the methodology that has been followed in the study. Section four focuses on the empirical results of the study based on the Greek case. Section five synthesizes, further discusses the results, presenting at the same time some concluding remarks.

2. Literature Review: Theoretical and Empirical Evidence

Joseph Schumpeter is considered to be the first economist to focus on innovation and its importance. According to him, innovation is a product (new one or change in an existing), a process new to an industry, an opening to a new market, the development of new sources of supply for raw materials or other inputs and changes in industrial organization (OECD 1997). Thus, innovation involves many and different things and this means that its measurement is difficult due to the broad nature, scope and products of innovation activities. This is the reason that innovation can only be measured indirectly and mainly with the use of indicators.

The existing bibliography has proposed several indicators for the description and measurement of innovation. The most common of them are the indicators that derive from R&D, patents and new products (Basberg 1987, Archibugi 1992). A patent is a document, which contains structured and detail information regarding the hidden invention and the probable or future technological innovation, and is accessible to the general public through the dissemination of such documents by a national or international authorized government agency (Huang et al. 2003). Each patent document is issued by a patent office and grants the owner a monopoly over the exploitation of a precisely defined technological advancement or incremental improvement (e.g. new device, apparatus, or process) over a stated period of time, which is usually 20 years. Generally an invention can be eligible for a patent, only if the innovation that this invention 'hides' is novel, involves a non-obvious inventive step, and could be commercially viable (Dernis and Guellec 2001, Dernis and Khan 2004).

Among the advantages of using patent data at the study of technological innovation are first the proximity of patents to the inventive and innovative activities, the wide range of fields covered by patents and the geographical scope of patents. Second, patents are characterized by their easy accessibility, high reliability and precise definition (Ernst 2001, Debackere et al. 2002). Third, patent data are accurately recorded and easily elaborated, while they can be used to examine and study different levels and kinds of analysis (e.g. technological, sectoral-industrial, national). Four, patent data are rather 'objective' indicators, as patent documents are examined and eventually granted by a single national patent office, based on specific criteria, while every patent is then classified to sectors, classes and main groups according to the same classification system (e.g. International Patent Classification) (OECD 2009). Finally, in comparison with or in contrast to other sources, patents are often the only timely measure of rapid technological change, particularly in the context of global competition and an important tool for assessing the performance of technological systems. For example patents permit the study of technological change since they represent inventive activity and output from applied research over different fields, countries, and time (Hullmann and Meyer 2003).

However, as every tool of analysis, patent data exhibit also limitations. First, obviously not all inventions become patents and not all patents become innovations. Especially for firms this has a dual meaning. Firms use the patent protection in order to be protected from competitors. However, they may choose to use other ways of protection, such as secrecy, very fast introduction to the market and so on. Second, every patent office treats patents equally, while they are not and nor do all patents exert the same economic impact and the same technological and economic value (Gay and Le Bas 2005, Wang 2007, Lee 2009). Third, the propensity to patent differs across countries, sectors, firms, fields and technologies and this difference overestimates or underestimates the results in terms of performance (Arundel and Kabla 1998, Mäkinen 2007). Meanwhile this difference is due in part to the level of protection afforded by the patent, but also to the possibility of protecting monopoly rights by other means depending upon market conditions. Forth, there are differences in patent regimes across countries and this means that it is difficult to be certain that one is comparing 'like with like'. In fact, it is widely accepted that there are differences among the various patent systems (e.g., United States Patent and Trademark Office, European Patent Office, etc.), due to variations in legal, geographic, economic, and cultural factors. For instance, some countries would require multiple patents for the same innovation which could be covered by a single patent in other countries.

This study uses patent data as a proxy and measurement indicator to elucidate technological innovation in Greece, taking advantage of their positives and also considering the negatives of patent data.

3. Methodology and Data

The data for this study is based on patent records issued at the Greek Patent Office during the period 1988-2012. The analysis relies on the use of patent grants. Thus, patent grants have been used instead of patent applications and this is related to a methodological choice of assigning higher value to this study and so to results. Based, therefore, on the fact that a patent is only granted when it contains a technological innovation which exceeds a certain level of newness, only patent grants can guarantee that. In addition, the paper uses the IPC system of patent classification, because the IPC system is application-based and thus facilitates both the identification of technological innovations and their assignment to different industrial sectors. The IPC is a hierarchy of codes, structured into different levels with several levels of breakdown primarily concerned with the technological characteristics of the invention. Last but not least, the paper uses the class level as its base and aggregation level. The IPC allows linking patents to one or more economic areas, but only when examining the class level. This is due to the fact that there is no natural or perfect correspondence between technological classifications and economic areas. This problem of classification refers primarily to the difficulties in allocating patent data, organised by technological classes, into economically relevant industries or product groupings. In this study the class level of aggregation has been used (>130 classes and >850 groups of technologies).

Based on the above methodological choices, the analysis is based on the elaboration of an original patent database, which has been constructed and elaborated especially for this study and according to the following steps: Step one, patent documents in paper sheets have been collected from the Greek Patent Office for the period of 1988-2012. Based on these patent documents a patent database has been constructed, which contains all patents (Greek and foreign) which have been granted by the Greek Patent Office, a total of 7841 patents. Second step, patents by Greek owners (Greek patents) have been separated by patents of other nationalities (foreign patents) based on the address of the assignee or patent owner. This part of patents composes the sample of analysis, which includes 5973 patents. Third step, each Greek patent has been classified to one or more technology sectors, sub- sectors, classes- subclasses and main groups (five levels of technology analysis) based on the number of patent codes that the Greek Patent Office has attributed to the referring patent. This means that if a patent has one patent code, it is described based on five levels of analysis, if it has two patent codes, it is described based on ten levels of analysis and so on. Forth step, each patent has been related and corresponded to one or more industrial sectors, indicating this way its potential application or industrial use. Fifth, indexes of technological specialization have been constructed, based on the form of Herfindhal index of concentration.

Some further remarks have to be clarified regarding methodology and elaboration and data: First, the total period of analysis has been divided to two sub-periods: 1988-2010 (period 1), and 2000-2012 (period 2). This enables examining the historical evolution of technological innovation in Greece and highlighting the existence of major technological fields, both in time and relative importance. Second, the technological content of patents is described at five levels of analysis, from the more general (sector, sub-sector) to the more detailed (class, main group), thus ending up to group of products or simple products. Third, the correspondence of patents into relevant industrial sectors is based on their main technological content, thus the first patent code assigned to each patent. In this way it is also avoided the problem of overlapping, while being focused on its main potential application or industrial use. Four, four different kinds of indicators have been constructed and presented in this paper and more specific indicators of patent counts per sub-period and total period, indicators of technological content at class technology level, indicators of technological specialization based on the size of the respective index of concentration and indicators of application or industrial use at NACE 2-digit level.

4. Main Results

The analysis shows that technological innovation in Greece is dispersed among the eight broad technology sectors. Shares higher than 10% have been recorded to the sectors of ‘human necessities’, which ranks first, ‘performing operations- transporting’, ‘fixed constructions’, ‘mechanical engineering- lighting- heating weapons- blasting’ and ‘physics’ which barely surpasses the 10% share. ‘Chemistry- metallurgy’ and ‘electricity’ range between 5-10%, while only ‘textiles- paper’ accounts for very low absolute numbers. ‘Human necessities’ are further focused on technologies of ‘agriculture’, ‘foodstuffs- tobacco’, ‘personal or domestic articles’ and ‘health, lifesaving, amusement’. ‘Performing operations- transporting’ is mainly related to technologies of ‘transporting’, while ‘fixed constructions’ to those of ‘building’. ‘Mechanical engineering- lighting- heating weapons- blasting’ is further specialized to technologies of ‘engines or pumps’ and ‘engineering in general’, while ‘electricity’ leads to ‘electric communication technique’.

The comparison between the two sub-periods of analysis (1988-2000 and 2000-2012) shows that there is no change in the two sub-rankings. However, there is change in the recorded shares between sectors. The shares of ‘Human necessities’, ‘performing operations- transporting’ and ‘electricity’ have been decreased and this reduction ranges between 10-15%. On the contrary the shares of ‘chemistry- metallurgy’, ‘mechanical engineering- lighting- heating weapons- blasting’ and ‘physics’ have been increased and this increase ranges between 18-41%, with ‘chemistry- metallurgy’ being characterized by the higher (42%). The sector of ‘fixed constructions’ exhibits a remarkable stability, accounting for the 14% of Greek patents and technological innovations during the whole period of analysis (1988-2012). The calculation of concentration indexes shows that concentration based on sectors is 0.186 for the whole period of analysis (1988-2012), 0.192 for 1988-2000 and 0.176 for 2000-2012, thus is being decreased gradually leading to more technological dispersion and variety. Inside sectors and at class level, concentration varies and ranges from 0.381 in ‘textiles- paper’, a sector with few patents, and 0.009 in ‘chemistry- metallurgy’. ‘Fixed constructions’ and ‘electricity’ are relatively sectors of high concentration, while ‘performing operations- transporting’ is a rather sector dispersed sector with many important classes.

Table 1 presents the 15 most important technology classes of the classifying Greek patents according to the IPC standards. A closer examination of the table shows that core technologies in ‘human necessities’ are those of (1) ‘medical or veterinary science- hygiene’, (2) ‘agriculture, forestry, animal husbandry, hunting, trapping, fishing’, (3) ‘furniture, domestic appliances, coffee mills, spice mills, suction cleaners in general’, (4) ‘foods or foodstuffs, their treatment, not covered by other classes’. These four technologies account for more than the 80% of the respective sector and are further specialized to ‘planting; sowing; fertilising; harvesting; mowing; animal husbandry’ and ‘preparations for medical, dental or toilet purposes’ at technology main group level. Main technologies in ‘performing operations- transporting’ are those of (1) ‘conveying, packing, storing, handling thin or filamentary material’, (2) ‘vehicles in general’ and (3) ‘ships or other waterborne vessels, related equipment’. Core technologies in ‘fixed constructions’ are those of different aspects of building, such as (1) ‘doors, windows, shutters or roller blinds in general, ladders’ and (2) ‘locks, keys, window or door fittings, safes’. In total technologies focused on building account for more than the 80% of the respective sector and are further specialized to ‘general building constructions; finishing works on buildings’. Main technologies in ‘mechanical engineering- lighting- heating weapons- blasting’ are those of (1) ‘machines or engines for liquids and various motors’, (2) 'heating, ranges, ventilating' and (3) 'engineering elements or units, thermal insulation in general'. Core technologies in 'physics' are those of different kinds of instruments, such as (1) 'computing, calculating, counting', (2) 'Educating and display' and (3) 'measuring, testing'.

Table 1: The 10% of the most important classes in Greece

Ranking	Technological classes	%
1	Medical or veterinary science, hygiene	9.20
2	Agriculture, forestry, animal husbandry, hunting, trapping, fishing	7.84
3	Building	6.40
4	Furniture, domestic appliances, coffee mills, spice mills, suction cleaners in general	4.51
5	Conveying, packing, storing, handling thin or filamentary material	3.71
6	Machines or engines for liquids; wind, spring or weight motors; producing mechanical power or a reactive propulsive thrust	3.26
7	Foods or foodstuffs, their treatment	3.16
8	Vehicles in general	2.90
9	Measuring; testing	2.88
10	-Doors, windows, shutters or roller blinds in general, ladders -Heating; ranges; ventilating	2.78
11	Locks, keys, window or door fittings, safes	2.16
12	Educating, cryptography; display; advertising; seals	2.12
13	-Computing; calculating; counting -Electric communication technique	2.03
14	Ships or other waterborne vessels, related equipment	1.65
15	Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation	1.61

Source: Own elaboration of Greek patent data.

The comparison between the two sub-periods of analysis at class level shows the withdrawal of some technology classes and the entrance of some others. Among the former, which account for 18 in total, the most characterizing cases are those of 'paper making- production of cellulose' and 'earth drilling-mining', while among the latter the most important cases are those of 'fabrics' and 'organic macromolecular compounds'**.** In addition, the further examination of classes highlights the very important increase in absolute and relative numbers of some classes, when moving from the first period to the second. These classes are related to the 'performing operations-transporting' ('spraying-atomising' and 'mechanical metal-working'), chemistry-metallurgy (e.g. 'treatment of water, waste, sewage or sludge', 'organic chemistry, 'biochemistry') and 'mechanical engineering- lighting- heating weapons-blasting' (classes 6 and 10b).

Table 2 presents the economic direction of the 15 most important technology classes, after relating them with industrial sectors of application and use. A careful reading of this table shows that the Greek technological innovation is related to the following industrial activities based on NACE codes: (1) chemicals (e.g. pharmaceuticals and pesticides-agrochemical products), (2) different kinds of machinery (e.g. agricultural-forestry, energy, office and computers, special purpose machinery, non-specific purpose machinery), (3) different kinds of equipment (e.g. medical, other transport, other electrical, industrial process control), (4) different kinds of instruments (e.g. measuring, optical), (5) products and final products from different materials (e.g. non-metallic mineral, fabricated metal, rubber-plastic, basic metal, wood), (7) general basic and consumer goods (e.g. food-beverages, domestic appliances, furniture-consumer goods), (8) electric and electronic equipment (e.g. signal transmission-telecommunications, television, radio receivers-audiovisual electronics) and (9) particular forms of vehicles.

Table 2: The 10% of the most important industrial sectors of application and use in Greece

Classes[1]	Industrial sectors of application and use
1	Medical equipment, pharmaceuticals
2	Agricultural-forestry machinery, pesticides-agrochemical products
3	Non-metallic mineral products, basic metals, wood products
4	Domestic appliances, furniture- consumer goods, fabricated metal products
5	Rubber and plastic products, Fabricated metal products, special purpose machinery, non-specific purpose machinery
6	Energy machinery
7	Food-beverages, special purpose machinery
8	Motor vehicles, other transport equipment, rubber-plastic products, other electrical equipment
9	Measuring instruments, non-specific purpose machinery, industrial process control equipment, medical equipment, motor vehicles
10	Fabricated metal products (100%) Fabricated metal products, domestic appliances, non-specific purpose machinery
11	Fabricated metal products
12	Optical instruments, signal transmission-telecommunications
13	Office machinery and computers (100%) Signal transmission-telecommunications, television, radio receivers-audiovisual electronics
14	Other transport equipment (100%)
15	Energy machinery, rubber-plastic products, fabricated metal products, motor vehicles, non-specific purpose machinery
[1]Classes 1-15 based on the taxonomy of table 1	

Source: Own elaboration of Greek patent data.

More than 60% of all Greek patents are related to the above activities. The table also shows that the majority of technology classes are directed to more than one industrial activities of different sectors, while a particular industrial sector may be related to more than one technology classes. The former is more representative in classes (5), (8), (9) and (15). The latter is clearer in the industrial sectors of ‘fabricated metal products’ and ‘non-specific purpose machinery’. However there are also technology classes and industrial sectors of application and use that are characterized by 100% ‘1 to 1’ correspondence. This is the case of class (6) to ‘energy machinery’, both classes (10) and (11) to ‘fabricated metal products’, class (13) to ‘office machinery and computers’ and class (14) to ‘other transport equipment’.

5. Conclusions

Innovation plays a key role in economic development and is therefore a primary concern for practitioners, policy makers, and researchers. Innovation description and measurement led, among other things to the theoretical and empirical analysis of patent value, which has attracted the attention of all related private-public agents for years and contributed to the better examination and interpretation of innovation. In this context, this paper aims at studying the production and the development of technological innovation in Greece based on patent data.

Results show that the production of technological innovation is related to specific technologies of 'human necessities', 'fixed constructions' and 'performing operations- transporting'. These are the most important innovation fields in quantitative terms. This is the Greek pattern but also the dominant pattern of other countries, with the exception of 'fixed constructions'. Countries like Denmark, Hungary, Poland, Portugal, and Slovakia are characterized by the same pattern, based on their patents grants at the U.S.A. patent office. On the contrary, Germany and France are characterized by different patenting trends: Their production of technological innovation is mainly concentrated in 'performing operations-transporting', 'electricity' and 'physics' (OECD 2011). In addition the comparison between Greece and other countries shows that Greece is first characterized by an unusually large share of patents related to 'fixed constructions' and, second, an insufficiency of technologies related to 'chemistry-metallurgy', 'physics' and 'electricity'.

Greece is a country with very severe fiscal and structural problems. Whatever Greek government does, it is necessary to 'build' a new development agenda and policy, and innovation plays a central role in this procedure. Therefore, focusing on the production of innovation is the main challenge, but to what direction? The country needs to balance between 'world' and 'endogenous' important innovations'. This means that Greece has to do two things: First, look for and then develop competitive innovations, investing and expanding its relative strengths in line with its industrial structure (e.g. innovations in 'fixed constructions'). The existing pattern shows that technological innovations in industrial sectors related to drugs-sanitary products and both the agricultural and construction industry are the most important. However, based on its geographical position and physical environment and in correspondence to future global needs, it can be argued that only innovations related to the agricultural and construction industry could be a viable technological direction. Thus, and in accordance with the paper results Greek innovation should focus on ecological building, sustainable forms of cultivations, renewable resources and saving in energy.

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