Renewable Energy Technologies in Greece: A Patent Based Approach

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Abstract- Energy was always a subject that preoccupied countries and their governments. Energy relied on the exploitation of fossil fuels for many years but since the 1970s alternative energy sources started being first developed and then diffused. The oil crises contributed to this change. At the same time the discussion on energy matters moved from self sufficiency to environmental concerns. This led to a new phase in the development of alternative energy and to the rise of new technologies in this field, the so called renewable energy technologies. The present study is designed to analyze the development of renewable energy technologies in Greece, as described by patents filed and granted by the Greek Patent Office. Specifically, the study presents an overview of the number and nature of patents for all types of renewable energy technologies, examines their technological content, identifies the major trends, if any, and puts all the above in a wider policy context while positioning Greece at the international context. Greece is a country that utilizes lignite for electricity generation, as its main domestic resource, while being heavily dependent on oil imports. The focus and the further development in renewable energy could help the country reduce energy import dependency while also contributing to environmental goals. Therefore, investing in renewable energy technologies could be a viable development solution, but this requires in-depth analysis of the country's overall pattern, trends and capacity in technological innovation. The study is designed to contribute to this effort.

Keywords- Greece; Patents, Renewable energy, Technologies.

1. Introduction

The oil crises of the 1970s were the starting point for the development and diffusion of renewable or alternative energy sources. The main aim behind this was reducing dependence on fossil fuels. During the oil crises, the primary focus was on increasing self-sufficiency with respect to energy sources. By the 1990s, environmental concerns had taken the forefront, leading to a new phase in the development of technologies in relation to energy from alternative sources. If patents describe and measure these new technologies, and empirical research argues that they do it accurately and correctly, then patent activity rapidly accelerated, especially after 2000.

The objective of this paper is the study of the development of renewable energy technologies in Greece, based on patent records. The paper is structured as follows: Section two discusses the theoretical and empirical framework of using patent records in such studies, presenting at the same time some of the most representing studies in relation to renewable energy. Section three focuses on some methodology issues, while also describing the data. Section four presents the main empirical results, while positioning Greece at the international level. Section five presents some concluding remarks, also starting a discussion on what policy should Greece implement towards renewable energy promotion and development.

2. Bibliography Review

Empirical research has extensively used patents in economic analysis aiming at the study of many and different parameters and fields. This is due to the fact that indicators deriving from patent data and records are characterized by many and important advantages. However, empirical research has also highlighted the limitations of patent indicators when used in economic analysis. Both advantages and disadvantages of patent indicators have been recorded in

relevant reports and studies [1]. In summary, it could be mentioned that patents are linked to and can measure both inventions and innovations. As a measure of inventions patents have a close (if not perfect) link to inventions. Patents cover a broad range of techniques, extending now to biotechnology and software, with first extensions towards services-related inventions (so-called "business methods") [2]. Patents enable researchers to study and to assess the level of inventive activity [3], the different types of innovation and technological competencies of organizations [4], the technology strengths of nations, the emerging patterns of technology diffusion, knowledge relatedness and spillovers [5].

However, patents also present strong weaknesses. Patents do not capture all innovations, but a restricted part of it. Some innovations are not patentable [6] and, even when they are, patents are not considered by firms to be the most efficient way of protecting and of appropriating innovations [7]. Moreover, it has been argued that firms are more likely to patent research that results in new products, rather than research that results in new processes [8]. In addition, surveys on patenting firms also indicate that the rate at which new innovations are patented varies across firms, industries, countries and patent offices, implying and meaning that the propensity to patent differs. Last but not least patents don't have the same value, although they are treated this way. Their value depends on their contribution to the economy, in technological or in economic terms. Defining this way the issue of value, there are patents of high value and those of very low value. However, patent offices don't discriminate among them and they are usually treated equally, which could be a problem in research [9].

Patents have also been used in the research and analysis of environmental parameters at both national- the economy as a whole- and sectoral level. Obviously, these studies include those of focusing on renewable energy matters. Generally, empirical research in this field concentrates in the measurement of environmental innovation. For example, it has been counted the number of patents in nine environmental fields (including alternative energy) and been studied the issue of diffusion of environmental technologies relying on international patent data to track patterns of diffusion [10]. Patent citations as well as pollution control technologies have also been studied [11]. There are other works which have been focused on the level of eco-innovation activities, the directions of research in certain environmental fields and their historical evolution, comparing patterns and results of different countries [12]. Certain of the above works also dealt with the competencies of organizations in environmental technologies focusing on the field of low emission vehicles (LEVs) [13]. Green chemistry patents based on US patents have also been investigated, and this analysis ended up with the identification of 3235 green chemistry US patents [14]. Finally, it could be also mentioned the work which studied the environmental technology strength of nations with the use of patent data, finding among others that Germany is the best performing country in a group of 12 countries, and Canada and Japan ranked equally at the second position based on the total ranking [16]. Last but not least there is another study, in which it has been presented data on six energy technologies using a 'patent landscaping' technique: wind, solar photovoltaic (PV), concentrated solar power (CSP), biomass-electricity, carbon capture and cleaner coal.3. Therefore, the bibliography on the research and analysis of environmental parameters using patent data is quite large, but it could be further developed, as it could be a very promising field.

3. Methodology and Data

The data for this study is based on patent records and documents during the period 1988-2010. The analysis relies on the elaboration of a 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 1988-2010. Based on these patent documents a patent database has been constructed, which contains all patents that have been granted by the Greek Patent Office, a total of 7187 patents. Second step, patents by Greek owners have been separated from patents of other nationalities based on the address of the assignee or patent owner. This part of patents composes the sample of analysis, which includes 5339 patents. Third step, each Greek patent has been classified to one or more technological sectors, sub-sectors, classes- subclasses and main groups 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. IPC allows linking patents to one or more economic areas, but only when examining the sub- 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 difficulties in allocating patent data, organised by technological sub- classes, into economically relevant industries or product groupings. In this study the technological sub-class level of aggregation has been used (more than 630 sub- classes). This correspondence is based on the main technological content of each patent, thus the first patent code assigned to it at NACE 3-digit level. In this way it is also avoided the problem of overlapping, while being focused on its main potential application or industrial use.

For the purposes of this analysis, renewable and alternative energy-related patents have been classified according to the application and granting year, country, technological sub-class, and applicant. There is a need to clarify one more parameter in relation to the followed methodology and this parameter has to do with first the definition of the so called 'renewable and alternative' energy- related patents and second the identification of patents in such fields. Empirical research in this field uses two kinds of methods: The first method is based on the examination of all patent codes classified to each patent

according to the international technology classification (IPC) and in relation to 'renewable and alternative' energy. Thus, the first method focuses on the technological content of each patent, as derived from its assignment to one or more patent codes and its interpretation. The second method relies on the 'creation' of keywords which should be also closely related to 'renewable and alternative' energy. Thus, the second method scans every patent in a dual way, both its short description and the interpretation of the technological content of each patent searching for these keywords. This paper examines the production and the development of 'renewable and alternative' energy- related technologies in Greece using both kinds of methods: It starts by examining all IPC codes assigned to each patent (one or more patent codes), then 'reads' both the interpretation of these codes and the short description of every patent and finally classifies or rejects each patent to 'renewable and alternative' energy- related technological field based on their definition.

4. Main Results

In total, 10% of patents can be included in the field of environment. Among them, nearly 65% of patents concern technologies in 'energy generation from renewable and non-fossil sources', which are further specialized in technologies in relation to 'renewable energy generation'. Among the rest sub- fields of 'environment', the 'general environmental management' is the most important. Its patents concern technologies in 'waste management', 'water' and 'air pollution abatement'. Experts in field of 'renewable energy generation' have identified eight different kinds of energy generation (e.g. wind; solar thermal, photovoltaic, thermal-PV hybrids; geothermal; marine; hydro tidal, stream or damless and conventional). The more detailed analysis of the above internal patent activity for the Greek case shows that technologies shows that most Greek patents are concentrated in 'solar thermal energy' and 'hydro energy', both 'tidal, stream or damless' and 'conventional'.

Regarding the economic direction of the above patents, results show that all environmental fields are related to more than one industrial activities of different sectors, while a particular industrial sector may receive patents from more than one technological fields. Obviously, the fields under consideration are multidimensional as well as complicate, mainly due to the variety of technologies they contain. There are technical sub- fields and industrial sectors of application and use that are characterized by 100% '1 to 1' correspondence. This is the case for example of first 'biomass', second 'fuel cells', third 'hydro- wind power', fourth 'hydrogen production', 'fertilizers from waste', 'recycling', and 'refuse-derived fuel from mass burn', fifth 'integrated emissions control', 'fuel injection' and 'technologies specific to propulsion using electric motor' and sixth 'solid waste collection' which are directed to 'coke, refined, petroleum products and nuclear fuel', 'accumulators and battery', 'energy machinery', 'basic chemicals', 'motor vehicles' and 'fabricated metal products' respectively. Patents in 'buildings- insulation' and 'noise protection' are directed to 'non-metallic mineral products', 'solar power' is linked to many industrial sectors but mainly to 'fabricated metal products' and 'electronic components', while 'waste management' as well as 'water pollution abatement' are, to a large extent, related to 'basic and other chemicals'.

In total Greece performs better than the total of EU- 27 members, OECD- members and World (all countries) in all under consideration environmental fields. The respective shares range from 4.865% to 7.413% for EU- 27 members in correspondence to the three main patent procedures, from 3.425% to 6.765% for OECD- members and from 3.353% to 6.737% for all countries (world- 100 countries) based on the OECD patent database. The above shares account for 10.610% (EPO), 4.693% (USPTO) and 12.475% (PCT procedure) in Greece respectively. However, it has to be pointed out that the USA patent office doesn't separate aside patents in the following fields: (1) energy generation from renewable and non-fossil sources, (2) combustion technologies withmitigation potential, (3) technologies specific to climate change mitigation and (4) technologies with potential or indirect contribution to emissions mitigation. This could mean that patent activity in the USA patent office in the above fields could have a different weight and thus influencing the Greek results.

Table 1. Greek patent activity in basic renewable energy fields granted by the Greek patent office and the foreign patent offices (EPO, USPTO, PCT procedure)

Selected environment-related technologies	Internal		External		
	OBI[1]		EPO[2]	USPTO[3]	PCT[4]
	% Total[5]	% Total	% Total	% Total	% Total
General environmental management	1.956	20.396	44.520	62.500	33.155
Energy generation from renewable and non-fossil sources	6.076	63.366	20.548	0.000	33.155
Combustion technologies with mitigation potential	0.000	0.000	4.110	0.000	2.139
Technologies specific to climate change mitigation	0.646	6.733	0.000	0.000	0.000
Technologies with potential contribution to emissions mitigation	0.323	3.366	8.219	0.000	16.578
Emissions abatement and fuel efficiency in transportation	0.285	2.970	22.603	25.000	10.695
Energy efficiency in buildings and lighting	0.304	3.168	0.000	12.500	4.278
Total	9.588	100.00	100.00	100.00	100.00

[1] OBI = Greek Patent Office. [2] EPO = European Patent Office. [3] USPTO = USA Patent Office. [4] PCT = Patent Cooperation Treaty Procedure. [5] Share of environmental technology field to the total technological taxonomy based on the IPC.

Energy generation from renewable and non-fossil sources (1)	Internal		External					
	OBI		EPO		USPTO		PCT	
	% Total	% (1)	% Total	% (1)	% Total	% (1)	% Total	% (1)
Renewable energy generation	61.188	96.563[1]	16.438	80.000			27.807	83.871
Wind energy	8.911	14.563[2]	0.000	0.000			8.556	30.769
Solar thermal energy	*13.663*	*22.330*	*12.329*	*75.000*			*9.626*	*34.615*
Solar photovoltaic (PV) energy	*0.198*	*0.324*	*4.110*	*25.000*			*6.417*	*23.077*
Solar thermal-PV hybrids	*7.129*	*11.650*	*0.000*	*0.000*			*1.070*	*3.846*
Geothermal energy	*4.950*	*8.091*	*0.000*	*0.000*			*0.000*	*0.000*
Marine energy (excluding tidal)	*0.000*	*0.000*	*4.110*	*25.000*			*4.278*	*15.385*
Hydro energy - tidal, stream or damless	*10.495*	*17.152*	*0.000*	*0.000*			*3.209*	*11.538*
Hydro energy - conventional	*15.842*	*25.890*	*0.000*	*0.000*			*2.139*	*7.692*
Energy generation from fuels of non-fossil origin	2.178	3.438[1]	4.110	20.000			5.348	16.129
Biofuels	*2.178*	*100.00*[2]	*4.110*	*100.000*			*5.348*	*100.00*
Fuel from waste (e.g. methane)	*0.000*	*0.000*	*0.000*	*0.000*			*2.139*	*40.000*
Total (2)	100.00		100.00				100.00	

Source: Own elaboration of Greek and OECD Patent Data.

Generally, the country presents a similar performance and thus can be grouped together with certain countries of the European Union, such as those of Cyprus, Czech Republic, Hungary, Poland, Portugal and Slovenia. Comparing between the internal (column 3- table 1) and the external patent activity at different patent offices (columns 4, 5, 6- table 1), it can be seen that the external patent shares at different environmental fields are quite similar, but different than the respective internal. More specific, patents granted by the Greek patent office are much more concentrated in 'energy generation from renewable and non-fossil sources'. Contrary to this pattern, Greek patents granted by all foreign offices concern more technologies in 'general environmental management', which rank first, then 'energy generation from renewable and non-fossil sources' is ranked at the second position, followed by technologies in relation to both 'emission mitigation' or alternatively to 'emissions abatement and fuel efficiency in transportation'. In addition, it seems that Greece's internal pattern is only similar to the respective of the patent grants to EPO (internal- 9.588% and EPO- 10.610%).

5. Conclusion

This paper has investigated the production and development of renewable energy technologies in Greece, relying on patent records. Based on the general Greek pattern there is a part of patents classified as 'environmental', which are further specialised and related to 'energy generation from renewable and non-fossil sources' and 'general environmental management'. Their share accounts for 10% of total patents granted in Greece during the period 1988-2010 and most of them concern technologies in 'renewable energy generation', based on the internal patent activity. Half of the above technologies concern 'solar thermal energy' and 'hydro energy- conventional'. Technologies in 'hydro energy- tidal, stream or damless' follow according to the total ranking and then technologies in 'wind energy', which are finally related to energy machinery. Figures and statistics show that the overall country's share at the European Patent Office is 0.1%, distributed among patents in wind energy, solar and waste. Greece performs much better in solar PV and onshore wind technologies, while based on the renewable energy country attractiveness the country is 21st among 40 countries.

Greece has a proposed binding 'renewable energy sources directive' target of 18% by 2020. Based on this target and in case this could be achieved, the 20.1% of gross electricity consumption could be covered by such forms of energy. Greece possesses a mature 'renewable energy sources' market especially for active solar thermal systems, hydro as well as geothermal installations in the heat sector. However, the current status and development of 'renewable energy' generation in Greece is mostly dominated by traditional renewable sources such as large scale hydro power. These are the facts for a country that utilizes lignite for electricity generation, as its main domestic resource, while being heavily dependent on oil imports. Renewable energy could help the country reducing its energy import dependency, while also contributing to environmental goals. Greece is already a leader, in the number of solar thermal installations on a per capita basis. The potential for wind is also quite high. There are many 'public and private' voices that insist that the investment in these technologies could be the only development solution based on the country's environmental advantages. However, this requires in-depth analysis of the country's overall pattern, trends and capacity in technological innovation. The study is designed to contribute to this discussion.

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