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The Portrait of Persistent Innovators in Greece

Maria Markatou

National and Kapodistrian University of Athens, Greece

Abstract

Persistence in innovation is very important for national and firm growth. This paper contributes to the study of innovation persistence at firm level, focusing on Greece. Empirical research uses patent and survey data for this purpose. In this context, innovation persistence is examined for a sample of 300 Greek firms. Innovation activities are measured through related patents and persistence is determined by the number of patents that each firm has developed during the period 1988-2010. The analysis focuses on the main firm features behind innovation persistence. Results show that innovation is persistent, as nearly half of firms patent more than once and for subsequent years during the whole period of analysis. The phenomenon of innovation persistence is more obvious among a total number of 30 firms, the so-called "heavy persistent innovators". Results show that these firms are involved in different economic activities at 2-digit level of analysis, have a small size based on their total number of employees, are characterized by different export shares, develop relatively many technologies based on the technological content of their patents and these new technologies are not usually related to their main production line. However, the analysis also confirms that there are inter-sectoral differences, implying that firm and technology-specific factors are important. The examination of firm-level innovation persistence could have clear implications for both innovation policy and the understanding of long-term industry dynamics. Especially now that Greece has started discussing restructuring its economy and re-planning its innovation policy, this paper could contribute to this discussion.

Keywords: Firms, Greece, Innovation, Patents, Persistence.

Introduction

Innovation is widely recognized as a major driving force for the growth of economy and the evolution of industry. Persistence in innovation is a key feature in the description and interpretation of the patterns and dynamics of technological change. At the macroeconomic level, innovation persistence allows for sustainable growth, while at the microeconomic level, persistence is related to firm growth. Innovation persistence occurs when a firm that has innovated once, innovates once again in the subsequent period. This phenomenon has become an important topic in applied industrial organization since the publication of the seminal paper by Geroski et al. (1997). After Geroski's work, all following empirical studies have argued that the firms' survival and competitive advantage largely depend on their ability to innovate over a longer period of time.

The study of innovation persistence is inevitably related to the discussion on the properties of the patterns of innovation activities. The existence of innovation persistence can be associated with the process of "creative accumulation" (Schumpeter Mark II model), where firms are large, oligopolistic competition is stable and turbulence weak. The absence of innovation persistence can be associated with the process of "creative destruction" (Schumpeter Mark I model), where firms are small, competition is strong and turbulence, described as entry and exit, is high (Malerba and Orsenigo 1996). From a theoretical perspective, innovation persistence can be seen as the result of

 Contact author: Maria Markatou E-mail: markatou@prd.uth.gr

three different but interrelated parameters: first, innovation activities are characterized by significant entry and exit barriers, as a result of the relevant upfront sunk costs for the set up of research infrastructures and the required long term investments which have to be reserved in order to capitalize R&D returns (Sutton, 1991). Second, the continuous interactions between the two processes of knowledge accumulation and creation of routines within the same organization eventually lead to the creation of dynamic capabilities, which further encourage the systematic reliance upon innovation as a competitive tool (Nelson and Winter, 1982). Third, successful innovation activities have a positive impact on firm, creating thus conditions for further innovation by providing higher permanent market power, reducing financial constraints and broadening the space of available technological opportunities.

Empirical research in this field is quite recent in terms of history but plentiful regarding the number of total studies and their contribution to the economic literature. They all agree on the fact that a lot of technological learning, competence accumulation and technological diversification take place among persistent innovators. Summarizing their results, they found evidence on the following: first, firm innovation persistence can be strong or week and rather a short-lived phenomenon, but generally it is positively related to profits. Second, innovation is persistent only for a small number of firms. Third, firm size is an important determining factor in innovation persistence. In fact, a minimum threshold size for total revenues (turnover) appears to be required for the firm to be able to fund persistent R&D activities. Fourth, innovation persistence plays an important role in explaining the concentration of technological activity, if the latter is measured by the share of patents owned by firms, the stability of the innovators' ranking and their innovative intensity. Fifth, persistence is related to inter-sectoral differences, which confirm the importance of technology-specific factors. High-tech industries exhibit higher innovative persistence than low-tech industries. Similarly, mature industries are more persistent than new industries. Sixth, innovation persistence is stronger among individuals than among firms.

This paper aims at examining the phenomenon of innovation persistence at firm level based on firm patent records in Greece. The description of the main features of innovation persistence at firm-level along time has clear implications for both innovation policy and the understanding of long-term industry dynamics. This paper is original in three ways: first, it represents a contribution to empirical literature on innovation persistence at firm level. Second, it focuses on firm features rather than just simply confirming or non-confirming the existence of innovation persistence. Third, it presents the Greek case, which has not been studied so far. The rest of the paper is organized as follows: section two describes the existing bibliography, summarizing the results of previous empirical studies on innovation persistence. Section three, discusses some issues of methodology and analyses the data used for this paper. Section four presents the main results regarding the phenomenon of innovation persistence in Greece. Section five concludes, highlighting ideas for further research and implications for policy.

Bibliography Review

The bibliography on innovation persistence is abundant. In general, empirical research in this field can be divided into two main categories: research that uses survey-based data and research that explores patent-based data.

Regarding the first group of studies, Duguet and Monjon (2004) suggest that persistence is strong at firm level, arguing however that the right theoretical modeling depends on firm size. Based on their results, persistence may have several origins, such as persistence of research activities, commercial success of past innovations, technological opportunities and probably dynamic increasing returns. Their study also reveals differences in behavior among small and large firms.

Roper and Dundas (2008), using innovation survey data for 3604 plants covered by the Irish Innovative Panel in the period 1991-2002, argue that both product and process innovations are strongly persistent. Among their findings is that size and ownership of plants matter. The persistence in the introduction of product innovations is associated to strategic variables, while the persistence in the introduction of process innovations is associated to market pressure. Inside sectors, they are all persistent, except for the sectors of paper-printing and electrical-optical equipment. Peters (2009) found strong evidence of persistence while studying German manufacturing and service firms for the years 1994-2002. According to the results, persistence is concerned with innovation inputs, R&D activities and innovation outputs, while it is confirmed that firms exhibit high levels of persistence in undertaking innovation activities. In addition, innovation behavior is permanent at firm level to a very large extent.

Antonelli et al. (2010), using a sample of 451 Italian manufacturing companies for the period 1998-2006, confirm the presence of significant persistence in innovation activities, but with significant variations, which are due to the typology of innovation under consideration. Their results show that persistence is higher in R&D investments, a fact that implies significant entry and exit barriers. Raymond et al. (2010) focus on Dutch manufacturing firms using firm data from three CIS, during the period 1994-2000. They suggest that there is no evidence of true persistence in achieving technological product or process innovations. However, after further examination they found evidence of true innovation persistence, when considering the input side and spurious persistence when focusing on the output side. Le Bas and Poussing (2012) examine persistence of innovation behavior at firm level (manufacturing and services sectors), contributing to the existing literature by explicitly distinguishing between single and complex innovation strategies. Using two waves of CIS, their results show that complex innovators are more inclined to remain persistent than single innovators. The results support the idea that differences in innovation strategies across firms are important for understanding the firm innovation dynamics.

Regarding the second group of studies, the work of Geroski et al. (1997) is a pioneer one. Studying the innovative history of UK firms during the period 1969-1988 and using two sets of data (e.g. patent and innovation data), they are searching for 'major' innovations. They find little evidence of persistence at firm level. Among their results is that larger firms have longer innovation spells, concluding that only very few firms innovate persistently and this happens only after a threshold level, which only a few firms ever reach. However, these persistent firms account for a very large share of total patents. The work of Crepon and Duguet (1997) is also related to the issue of innovation persistence. Using a panel of R&D performers operating in France and their patents, they find that the effect of lagged patents on the current number of patents is significantly positive, which suggests a rather strong persistence in innovation among formal R&D performers. Malerba et al. (1997) examine persistence and heterogeneity in innovation activities, studying five European countries for the period 1969-1986 and for 33 technological categories. Their econometric results confirm the existence of both persistence and asymmetries. Both phenomena determine the patterns of innovative activities across countries and sectors, while the influence of market structure is less clear. Malerba and Orsenigo (1999) investigate the patterns of innovative dynamics, as determined by the processes of entry, exit and survival, using patent data for six countries, finding that innovative activities are characterized by high degrees of turbulence. They argue that a large number of new innovators are occasional and that only a small number of entrants survive and succeed in remaining innovative after the development of their first patent. In addition, persistent or serial innovators keep this behavior for many years. Cefis (2003) examines innovation

persistence and profitability at firm level, confirming the phenomenon of persistence and arguing that innovative activities, at least those captured by patents, are persistent.

The rather weak innovation persistence is found in the study of Cefis and Orsenigo (2001), who examine persistence across countries, industries and firms by size, arguing that both persistent and non-persistent innovators have a strong tendency to remain in their state. Their study finds heterogeneity across industrial and size classification, while persistence tends to increase with firm size. However, the relationship between firms' size and persistence is country-specific and definitely not a simple one. Moreover, they provide evidence of inter-sectoral differences, which confirm the importance of technology-specific factors and imply that the sustained innovative performance has to be supported by a systematic and continuous process of accumulation of resources and competencies. Le Bas et al. (2003) conduct an empirical analysis of innovation persistence and they identify four types of innovation behavior: single innovators, which produce few patents and compose the 71% of the sample; heavy innovators, which produce many patents and account for only the 2.2% of the sample and medium and sporadic innovators. Latham and Le Bas (2006) study innovation persistence relying on French and US patents. Their results confirm the phenomenon of persistence, but only and mainly in a limited time span. Their work is different in the sense that they also examine innovation persistence among individual inventors. They find that innovation persistence is stronger among individuals than among firms, highlighting the important role of "serial inventors". Finally, Huang and Young (2010) examine innovation persistence and its determinants in Taiwan's manufacturing sector, using a panel dataset of manufacturing firms over the period 1990–2003. Results show a strong effect of state dependence, after controlling for firm heterogeneity and initial conditions, supporting the existence of innovation persistence. However, persistence is stronger in scientific industries relative to non-scientific industries.

In conclusion, the evidence of the literature on the issue of persistence in innovation is mixed. Most works identify elements of persistency but do not provide a convincing consensus about its determinants and, most importantly, about their contribution in the dynamic process of technological change. In particular, the patent- based works suggest that persistence exhibits strong values only in the case of heavy patentees. On the contrary, survey data analyses find stronger evidence of innovation persistence.

Methodology and Data

This paper studies innovation persistence based on patents grants which are owned by Greek firms and have been collected for a total of 23 years (1988-2010). Every firm patent is an innovation, and therefore the total number of patents per firm during the whole period of examination is the unit of analysis. Thus, patents represent an indicator of innovation carried out by firms. The advantages and disadvantages of using patents for this purpose are well known (see Markatou 2011 for a review). Patents in this paper are not interpreted as a direct measure of output, but rather persistence in patenting is considered to express a specific behavior by which firms are systematically engaged in innovation activities. For methodology and quality reasons, the whole period of analysis has been divided to three sub-periods (e.g. 1988-1997, 1998-2005 and 2006-2010) in order to extract better and more reliable results.

Methodologically, for a Greek firm being considered a persistent innovator, it has to fulfill the following three criteria: first, the firm has to develop more than one innovation (e.g. each firm has to patent more than once). Second, these per firm innovations have to be recorded in all three different sub-periods under examination. Third, the total number of innovations per firm has to be higher than ten (e.g. only firms with more than ten patents are

included in the sample and are, thus, characterized as persistent innovators). Based on the above three criteria, the sample comprises of 30 firms, for which the authors argue that they don't consider their innovation activity as an accidental incident and they don't just enter or hit and then forget it and exit from a technological point of view. On the contrary, the main argument is that these firms consider their patent activity as a systematic one inside their production activities, while representing a certain entrepreneurial behavior and culture. Thus, the main database includes 30 firms, for which economic and other data have been collected in order to study their economic profile. In this context, the parameters of activities and products, ownership, size, age, exports and patent activity in a foreign office are examined. Particularly for size and exports and, generally, for all quantitative parameters, data has been collected for five years, namely those of 1990, 1995, 2000, 2005 and 2010.

In addition, some other parameters have been examined in order to offer more quality to this paper: first, "Technological differentiation in origin"; second "economic differentiation in direction-use"; third "coincidence between technological and production activities" and forth "placement of new technology inside or outside the main production activity or the complementary activities". The above parameters take the form of indicators, constructed and defined as follows: the first indicator relies on patent subclasses according to the IPC methodology. If subclasses differ, there is a first indication of "technological differentiation in origin". The high or low values are determined by the relative high or low reverse concentration indexes (e.g. reverse Herfindhal concentration index). The second indicator relies on 4-digit economic activities according to the IPC-NACE concordance methodology. Based on this methodology, each patent code is classified to a specific technological subclass and is related to a specific 2-digit economic activity. A correspondence table between technological subclasses and 4-digit economic activities has been constructed. If 4-digit economic activities differ, there is a first indication of "economic differentiation in direction-use". The high or low values are determined by the relative high or low reverse concentration indexes (e.g. reverse Herfindhal concentration index).

The third indicator relies on the comparison between production and technological activities, when the latter are "translated" into production activities. Each firm is involved in certain 4-digit production activities (production origin sector). Meanwhile, each patent code is classified to a specific subclass, which then is related to a specific 2 and 4-digit activity (economic direction-use sector). This indicator is derived from the comparison between the 4-digit codes of production origin with those of economic direction-use for each firm. The forth indicator relies on the previous part of analysis, meaning that if firms' production and economic activities coincide at 4-digit level, then patents are placed inside the main or total production line. Comparing between production and economic activities at three levels of taxonomy allows for the examination of the extent to which firms develop patents outside production or inside production, but focusing on one or more new activities. In total new technology may involve new activities at 2-digit level, new activities at 3-digit level (existing industrial branch but new 3-digit activities) or new activities at 4-digit level (existing industrial branch but new 4-digit activities).

The following section presents the main results, starting by presenting the overall firm trends in patenting during the period 1988-2010, as measured by the total number of patents per firm, and continuing by describing the main economic features of these persistent innovators. Thus, the section starts by providing an answer to the main research question of "is there persistence in innovation" and continues by analyzing the firm's profile behind innovation persistence.

Main Results

Nearly 43.40% of Greek firms have developed more than one patent during the

period 1988-2010, executing innovation activities during different time sub-periods. Thus, persistence in innovation exists. Among these firms there are totally 30, which are characterized by their high patent activity (>10 patens), composing in a sense a group of "heavy innovators".

The economic activities of persistent innovators differ. However, it is obvious that there is a small concentration in 'fabricated metal products' and 'machinery-equipment' (five and eight firms respectively). The list of the rest 17 firms is filled by four firms activated in non-manufacturing branches, two of them being involved in 'wholesale trade'. At 4-digit level, the firms of 'fabricated metal products' and 'machinery-equipment' are involved in different activities but with a small concentration in the manufacture of 'locks and hinges' and 'other special purpose machinery', respectively. On the contrary, firms in 'chemical products' are further specialized in the 'production of pharmaceuticals' (e.g. production of drugs), while firms in 'electrical machinery-apparatus' are in the 'manufacture of electricity distribution and control apparatus' (e.g. products that are related to 'special electronic material and lighting devices'). Ten persistent innovators have also protected their patents applying to a foreign patent office. However, the further study of their external patent protection shows three things: first, firms prefer to apply at the European patent office (6/10 firms) and then choose the PCT channel of protection (international protection). Second, all most persistent firm innovators and regardless of their economic activity have applied for protection in a foreign patent office. Third, firms in 'chemical products' and 'electrical machinery-apparatus' are more active in protecting their patents to a foreign patent office. In fact, their involvement in external patenting and protection to one or more foreign offices is absolute.

The large majority of persistent innovators have been established after 1956. However, firms with external patent activity are younger, being established during the period 1967-1976, while for 4/5 the protection and the grant of the first patent was the opportunity for the establishment of a firm. This means that these seven firms were individual innovators before their first patent. Firms are characterized by different sizes based on their total employment. However, half of them are very small employing up to 50 employees in total. Most firms in 'machinery-equipment', 2/3 firms of 'electrical machines-apparatus' and all firms in 'wholesale trade' are classified in this class of size. Combining the number of employees with the number of patents per firm (patent intensity), the higher patent intensity is recorded in a firm of 'wholesale trade' and the lower in a firm of 'electronic-communication equipment'. Generally, higher values of patent intensity (≥0.5) are mainly met in the very small firms of 'machinery-equipment' with external patent activity where the time of the first patent coincides with the establishment of their firm. On the contrary, low values of patent intensity are met in relatively large firms (more than 300 employees), which are activated in different economic branches.

Most of firms (90%) export their products, showing larger or smaller export shares. An exception to this pattern is the firms of 'wholesale trade' and 'computer-related activities', for which it is rather rational not to record export activities. The export shares of firms range from small (5-10) to very large (>50). Half of firms of 'machinery-equipment' export more than the 30% of their products. Nearly all firms with external patent activity export abroad, while half of them exhibit very large export shares. At the same time, the export orientation-destination of products is related to the external patent office that the firm has chosen to apply for.

More specific, all firms that have protected their patents to USA export to USA, all firms that have protected their patents to EPO export to Europe and especially to the countries of European Union and most firms that have protected their patents through the PCT procedure, are firms with a wider export policy, selling their products

in north and south America, Asia and Oceania.

The "technological differentiation in origin" ranges from 0.941 to 0.170. The number of new technologies per firm does not depend on firm activity, since in branches with many firms, the above indicator ranges from very low to very large. The only exception to this pattern is 'electrical machinery-apparatus', where all firms exhibit high levels of "technological differentiation in origin". The analysis shows that this fact depends on the parameter of high or low patent activity. In fact, the number of patents per firm is positively correlated to the recorded technological differentiation in origin. The "economic differentiation in direction-use" ranges from 0.910 to 0. In general, persistent innovators develop different technologies, which however end up in similar economic activities. In most firms of 'fabricated metal products', 'chemical products' and 'electrical machinery-apparatus', the technological differentiation in origin exceeds the respective economic. The analysis shows that this indicator is independent of firm activity, with the only exception of 'food products-beverages' and 'electrical machinery-apparatus'. In addition, this indicator is negatively correlated to the recorded firm patent activity.

The "coincidence between production and technological activities" at 4-digit level varies showing that there is quasi absolute deviation between production and technological activities for 12 persistent innovators. On the contrary, high or absolute coincidence is exhibited in the heaviest innovators of the sample. Therefore, firms are characterized by different trends concerning this indicator. This indicator is independent of both the firm and patent activity. However, firms with more technological complex patents (e.g. patents with more than codes) show a different behavior, developing patents that are placed inside the existing production line. Regarding the last indicator (e.g. placement of new technology inside or outside production), it can be shown that persistent innovators behave differently, even for those being activated in the same economic activities. Generally, new technology is directed either to a new economic branch, either to one or more 3-digit and 4-digit activities. The trends are mixed without a dominated pattern, implying that the recorded trends are independent of both firm and patent activity. The only safe derived result is that the heaviest innovators tend to develop technologies, which are placed inside the existing production line, aiming at the exploitation of one or more new 3-digit activities.

Conclusions

Based on the definition of innovation persistence, the analysis that proceeded confirms the existence of innovation persistence in Greece. The phenomenon is more intense among the so-called "heavy innovators", which compose a sample of 30 firms, in which this paper has mainly focused on. Their economic features differ, showing differences in age, size, level and size of patent activity and exports. Half of them, however, are involved in 'fabricated metal products' and 'machinery-equipment', complementing thirty years of operation and they need from ten to thirty years to develop their first patent. In addition, nearly half of them are very small in size and are characterized by low enough and very high levels of export activities. For six out of thirty firms, the development of the first patent was the opportunity for the establishment of a firm. Among them are four involved in non-industrial activities and two of them are firms involved in 'wholesale trade'. In fact, the highest patent intensity has been recorded in one of the two above firms.

A further typology and grouping of these "heavy innovators" shows that firms in 'food-beverages' are relatively large and characterized by medium-high levels of "technological-economic differentiation", while their new technologies are placed outside the main production line. Firms in 'chemical products' protect their patents abroad. Their exports shares are low and they are characterized by medium levels of "technological-economic differentiation",

while their new technologies are placed inside the main production line. Firms in 'metal products' present medium export shares, being characterized by medium-high levels of "technological-economic differentiation", while their new technologies are placed also inside the main production line. Firms in 'machinery-equipment' are very small but exhibit relatively high export levels. Different levels of "technological-economic differentiation" are recorded, while their new technologies are placed both inside and outside the main production line. Finally, firms in 'electrical machines-apparatus' present high external patent activity. Their size being very small, their export shares medium and before their first patent they were "individual innovators". Their new technologies are placed outside the main production.

Results may have important implications for public innovation policy regarding targets, tools and particularly measures. The Greek government has used several and different measures to promote innovative activities since the 1980s. It is a main belief that funding and assisting to R&D activities is more likely to create persistent effects in the long term. The provision of further fiscal subsidies is of little importance, as their results are static, short-term and unlikely to change routines and accumulate knowledge. If a favorable industrial environment is the issue for Greece, then there is a need to focus on innovation persistence, as behind it elements of path-dependence, innovation patterns and industrial dynamics are hidden, all of them necessary for building sustained national growth and success. This paper is a first research effort to study innovation persistence in Greece. Obviously, more research has to be done, in the direction of examining both the determinants of persistence and its results on firm profits. Empirical research has identified many factors that determine innovation persistence, such as firm size, technological opportunity and recently organizational behavior. Future research could be directed to this kind of analysis and results could further contribute to targets and measures.

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