Abstract: Measuring the innovative performance of European Union (EU) is vital to assist in defining public policies that can contribute to stimulate innovation. This study aims to examine the socio-economic factors that contribute to the EU innovative performance. In order to validate the research, the empirical study uses two linear regressions, considering as dependent variables, respectively, the patents required and the percentage of innovative sales, with the objective of identifying the factors that most influence innovation outputs. This study concludes that the most important variables for innovative performance (measured as number of patents) are private R&D, percentage of innovative firms and public R&D. Additionally, the results can provide important clues to support the definition of public policies that can stimulate innovation.

Keywords: EU’s innovative performance; innovation drivers; innovation effects; innovation outputs.
1 Introduction

The outputs of innovation are difficult to measure due to their diversity that includes results from:

a  completion of ideas and projects in the innovation pipeline

b  the expansion of innovation capacity at the firm.

However, we can identify at least three arguments to support the importance of measuring innovation. Firstly, the assessment of innovation is important to support theoretical analysis and to contribute to innovation theories. The statistics can be used to test theories of innovation and to enlarge knowledge about technological change. Innovation is considered a key factor for economic growth (Markatou, 2013), competitiveness, productivity and employment. Secondly, the evaluation of innovation is important for the development and implementation of public policies. Statistical indicators on innovation and technological change could sustain the identification of strengths and weakness. And, also to provide strategically sources to support successful innovation policy. Third, the outputs of innovation are also important for the development of corporate strategy. Data on the technological and innovation capacity of different countries facilitate a better understanding of the geographical contexts in which
companies can develop and arrange their innovative activities and assist in the decision to make the necessary investments (Pass and Poltimae, 2010).

The present research aims to determine the innovative performance of European Union (EU) countries and identify the intrinsic factors that may contribute to this performance. To achieve this purpose this paper has two parts. First, through a literature review, identify the intrinsic factors that contribute to innovative performance in EU. And secondly, supplemented by an econometric study that applies a linear regression, seeking to highlight the aspects that contribute most to the innovative performance.

Innovation brings several benefits, such as increase productivity, contributes to economic growth (Markatou, 2013) and, consequently, increases competitiveness (Gust-Bardon, 2014). In this context, is crucial identify the factors that contribute to economic performance and propose public policies that can stimulate innovation. This research aims to cover a gap in empirical studies about innovation and test a set of understudied variables (Pass and Poltimae, 2010). This research may contribute to generate proposals that, if properly disseminated, could encourage companies to pursue innovation strategies, highlighting the advantages associated, in particular, with the competitiveness gains and sales growth.

2 Literature review

2.1 Innovation: looking for a definition

It is not possible to find a unanimous definition of innovation. For Schumpeter (1934), innovation is the successful commercialisation of a new product or service due technical changes or, more generally, is a new combination of knowledge, which may be primordial knowledge, complemented by new discoveries. Schumpeter (1934) defined the existence of five types of innovation:

- introduction of a new product or improvements in an existing product
- innovation for a new industrial process
- the opening of a new market
- development of new sources of supply of raw materials or other inputs
- changes in industrial organisation.

Amabile (1996) defines innovation as the successful implementation of creative ideas in an organisation. Consequently, the creativity of individuals and teams is a starting point for innovation (Nunes and Balsa, 2013), being a necessary but not sufficient condition, since successful innovation depends on other factors. Innovation may arise not only from creative ideas within the organisation but also from knowledge and technology transfers.

Fagerberg (2005) considers important to distinguish invention from innovation. Invention is the emergence of an idea for a new product or process, in turn; innovation is the first attempt to put an idea into practice. While inventions occur, for example, in universities and innovations occur primarily in companies. To transform an invention into an innovation, a company usually needs to combine different types of knowledge, skills and financial resources. Innovation requires learning about how to transform technologies and access markets in order to improve quality and reduce production costs. But, the
innovation process is uncertain for the reason that what needs to be learned is known only during the process of innovation itself (Lazonick, 2005), that is why Krozer (2012) considers that “an innovation process evolves from a ‘bright idea’ of an inventor to implementation by users. The process is driven by entrepreneurs who anticipate profits from investment in technology development but who are uncertain if research and development will provide technology that can be demonstrated, manufactured and sold to users, who have to take the risk in buying something new”.

Several definitions of innovation share the idea of novelty. Camison-Zornoza et al. (2004) refers that innovation captures the novelty of an idea that aims to increase organisational performance. Others define innovation as the adoption of an idea or behaviour concerning a product, service, device, system, policy or program that is new to the organisation (Damanpour and Gopalakrishnan, 2001).

2.2 The importance of innovation measurement

Nations can achieve economic gains by building infrastructure, improving institutions, reducing macroeconomic instability or improving human capital. However, in the long term, when all other factors are at maximum capacity, the conditions of life may only be improved through innovation (World Economic Forum, 2010) and through the stimulation of innovation and regional development creating, for example, laws that facilitate the innovation process (Kenny et al., 2012). According to Pass and Poltimae (2010), innovation has been measured, mostly from simple indicators, such as investments in R&D and number of patents; however, these indicators generally reflect only partial aspects of the complex phenomenon of innovation and could not provide a comprehensive view. These indicators do not capture the outputs of innovation and cannot be correlated with innovative performance.

Hence, the role of composite indicators of innovation has grown remarkably in the evaluation of innovation processes in recent decades. It is the best tool available for analysing the environment for innovation and performance, especially at the national level (Pass and Poltimae, 2010). Innovation is currently an essential determinant of value creation in companies and contributes to economic growth (Markatou, 2013). Therefore, measuring innovation has become a significant concern for both private companies and governments (Cañibano et al., 2000), because innovation is positively correlated with increases in productivity (Martin and Nguyen-Thi, 2010).

The ability of firms to compete abroad and in domestic markets depends crucially on innovative products that can be produced and sold at attractive prices. In the short-term, productivity and labour costs are important factors of competitiveness. In the long run, the ability of companies to innovate and their R&D expenditures can be key determinants of competitiveness (Cleff et al., 2005). According to Demirel and Mazzucato (2012), that conducted a study in the pharmaceutical industry, although R&D has, historically, been boosting firm growth, positive relationship between R&D and firm growth is only found for small pharmaceutical firms that are able to patent persistently (at least for the last five years). This means that in this sector, only these firms have been increasing their competitiveness through R&D. Surprisingly, large firms efforts in R&D are unlikely to drive sales growth. It would be important to study other sectors of activity to help policymakers to better define actions to increase R&D productivity.
The conditions in domestic country may enhance the propensity of firms to innovate and internationalise, particularly, to settle a high degree of uncertainty, which will be offset by the presence in other markets (Balabanis and Katsikea, 2003; Dimitratos, 2004). According to Spronk and Vermeulen (2003), performance refers to the results of an activity (or set of activities), i.e., the results achieved after the activity has started. It is the performance obtained by an activity or a set of activities. The objective of this study is measuring the performance of innovative activities. For this, we use input and output indicators. Wagner-Döbler (2005) argues that the input indicators capture what is used to produce knowledge, while output indicators deal with the outcome of knowledge production. Then, the outputs are related to the possible consequences of innovations on economic growth, employment, productivity, establishing itself as an important resource for policy makers and to the goals of their innovation policies (Pedersen, 1977).

Bowen et al. (2010) conducted a cross-sectional study seeking to define what contributes most to the innovative performance, their research suggested that innovation has been measured in several ways. Some studies use traditional input measures, such as R&D expenditure, R&D intensity or number of patents (Artz et al., 2010). Others focus on output measures, such as implementing processes (Huang et al., 2010) or launch of new products (Molina-Castillo et al., 2011; Otero-Neira et al., 2010). There is a proportional relation between patents and R&D expenditures despite the propensity to patent differs across industries and although patents can be use as both inventive input and output (Griliches, 1990), in this study we will use patents as output of R&D activities and input of innovation. This means that patents are the result of R&D activities and are precursors of innovation, because a patented invention is only an innovation if accepted by the market (Fagerberg, 2005).

One of the main reasons to conduct comparative studies on the performance of innovation systems is to promote learning and improve the performance of territories, research groups and countries [Main (1992) and Niosi (2002) and Dou (2004) cited in Edquist and Zabala (2009, p.6)]. In this sense, the main objective to develop comparative analysis (benchmarking) “is to assist policy summarizing a series of innovation indicators at national, regional or sectorial level, allowing a comparison of the relative success or failure of a given system of innovation, or by identifying specific aspects of the innovation system that had a good or bad performance” [Arundel and Dutch (2008) cited in Edquist and Zabala (2009, p.6)].

Despite the existence of many contradictory studies, is widespread belief that innovation activities not only directly influence the productivity of an economy but can also promote economic growth through new business formation, leading to the growth of employment and other outputs. Innovation encourages and facilitates entrepreneurs to create new organisations in order to enter into certain industries, characterised by an entrepreneurial technological regime (Hasan and Tucci, 2010). Also, according with Hashi and Stojcic (2010), innovation allows companies to differentiate from their rivals (through new products, processes, reduce costs or organisational improvements).
2.3 Effects of innovation

2.3.1 Economic growth and productivity

Innovation has been seen as a key element to promote economic growth in several countries, that is why governments stimulate it. Keynes advocated moderate state intervention and only to avoids crisis and maintain the balance (Roncaglia, 2005; Samuels et al., 2003) while Arrow (1962) advocates support for R&D activities because these have the characteristics of a public good that generates positive externalities. The empirical evidence confirms the relationship between innovation and growth and according to Schumpeter (1942), innovation is essential to change the existing balance and to promote the emergence of new products. This means that governments must understand the importance of innovation and develop policies to strengthen their efforts and results. Innovation involves the production of new knowledge, R&D, software, human capital and organisational structures. These factors are essential to obtain productivity gains and to maximise the efficiency of new technologies. These intangible assets have become strategic factors for value creation. Also, their role in the economy becomes important as tangible assets, representing more than 12% of the GDP in some countries (Organisation for Economic Cooperation and Development, 2010a). Innovation is critical to the global economy, nations and regions, especially in the current context in which it seeks to overcome the effects of the global economic crisis (Sivak et al., 2011). Innovation contributes to economic development (Freeman and Soete, 1997) and promotes entrepreneurship (Souza, 2009), and is, therefore, surprising that economists of innovation are not participating in the debate on the causes and impacts of the current global crisis (Filippeti and Archibugi, 2011). However, since Schumpeter, we already know that innovation is a key source of economic fluctuations. After his contribution on business cycles (Schumpeter, 1939), the relationship between innovation and the dynamics of economic development has been widely discussed in the literature, particularly after the recession of the ’70s of the last century (Mensch, 1979; Van Duijn, 1983; Freeman, 1984; Tylecote, 1992; Perez, 2002).

In current times of crisis is particularly important to encourage innovation as it is essential to know which national economic and social factors contribute to improve innovative performance (Archibugi and Pianta, 1992; Archibugi and Michie, 1997; Lorenz and Lundvall, 2006), as for example, the quality of scientific and technological institutions, the education system, the structure of the labour market and industrial specialisation (Filippeti and Archibugi, 2011). It is widely accepted that innovation is a necessary premise for the economic growth of a country, region or business. The concept of innovation and measurement methods has been the subject of constant debate for decades. Undoubtedly, measuring innovation and its dynamics assumes a huge importance for theoretical and empirical analysis of growth models and to support the decision making process of potential investors (Pass and Poltimae, 2010). Additionally, productivity is an important factor for competitiveness (Cleff et al., 2005) and it is relevant to know the impact of innovation on economic growth and productivity, in order to assist policy makers and to support macroeconomic decisions (Pedersen, 1977).

Innovation influences directly productivity and promotes economic growth (new business creation), and consequently contributes to create wealth (Hasan and Tucci, 2010).
2.3.2 Technological diffusion

Innovation enables the development of knowledge. According to Jaffe (1986, p.984): “As knowledge is inherently a public good, the existence of technology research efforts of other companies, can allow a certain company, to achieve better results than others, with less efforts of investigation”. Thus, companies who are actively looking for opportunities to explore the dissemination of knowledge will have a competitive advantage, assuming that these companies have sufficient absorption capacity to make effective use of this knowledge. In fact, this knowledge comes mainly from public or semi-public sources, such as Universities and Research Laboratories (Brouwer et al., 2008). Companies can also obtain information to support their innovative activities on their competitors and through open sources such as conferences, meetings, magazines, customers and suppliers which may create spillover effects that lead to new technological opportunities (Huang et al., 2010; Kahn, 2007). The ability of a firm to innovate and take advantage from the technology spillover effects depends on the level of R&D, human capital and their involvement in international trade. Overall, the literature suggests that innovation and technology transfers are important sources of productivity (Apergis et al., 2008).

Thus, the diffusion of knowledge is a positive externality, which benefits the entire economy, contributing to its advancement and to a more efficient and diversified use of existing resources (Chen and Yang, 2011). According to Luckraz (2008), the existence of spillover effects drives economic growth, since the acts of imitation from the followers are seen as a stimulus, putting pressure on the industry leader to innovate and consequently stimulates the economy growth.

The public research system plays several roles in innovation systems: education, information, development of skills, problem solving, creation and dissemination of knowledge, development of new tools and transferance of knowledge. Thus, they are an essential source of spillovers that may occur during the execution of these activities. Public research institutions have been the source of great scientific and technological advances that have become innovations. The existence of public research institutions can also shape the ability of a region to innovate, since these institutions act as an attraction for high-tech companies and improve R&D of multinational companies (Organisation for Economic Co-operation and Development, 2010b).

The circulation of knowledge is essential for innovation. The new ideas arise from the combination of existing knowledge from multiple sources. The dissemination of knowledge is also essential for the productivity that, in firms, increases with the application of knowledge acquired (Organisation for Economic Co-operation and Development, 2010b), this knowledge can be increase by social capital – connections between different actors (Vejzagic-Ramhorst et al., 2012).

The literature (Nambisan and Sawhney, 2010) suggests that sacrificing future growth oriented to innovation on behalf of current financial constraints is likely to be regret in the long run.

The solution to enable companies to continue their innovation agenda without straining their scarce internal resources is to adopt a system of strategic networking of innovation that enhances external resources. This approach focusing on exploitation of resources, capabilities, external networks and communities, improves or expands the scope of innovation, the quality of innovation outcomes and fosters the creating and dissemination of knowledge (Nambisan and Sawhney, 2010).
2.4 The national innovation system

National capacity for innovation is defined as the potential of a country to produce a stream of commercially relevant innovations (Furman et al., 2002). Faber and Hesen (2004, p.194), consider that “the behaviour of innovating firms will depend on their own decision-making, but that the set of considered options is shaped by institutions that constitute constraints and/or incentives for innovations, such as laws, health regulations, subsidies, taxes, public expenditures, etc. Additionally, micro-economic conditions (e.g. market conditions, competition, price setting) and macro-economic conditions (e.g. wealth, inflation, openness) will influence the decisions about innovation taken by firms”

In summary, the concept of a NIS is composed by two categories of variables:

1. variables related to innovation processes within and between companies
2. variables related to infrastructure to support innovations that facilitate companies’ innovation process.

These categories represent the structural dimensions of the concept of NIS. From a functional perspective, the innovations developed by companies can be conceived as transformation processes promoted by various input variables and resulting in output, represented by variables that indicate product innovations and/or process (Faber and Hesen, 2004).

Thus, for Faber and Hesen (2004), SNI variables can be classified into:

1. output variables, i.e., patents and sales of new or substantially improved products
2. process variables, i.e., difficulties faced during the process of innovation, use of external sources of information and cooperation for R&D
3. input variables, i.e., innovation activities.

The present study follows the model proposed by Faber and Hesen (2004) and considers as output variables of R&D activities: patents and sales of new or substantially improved products.

2.4.1 Economic conditions imposed by the national infrastructure for innovation

The innovation trajectory followed by each nation depends on several structural features of their economy. These structural features provide directions about the dominant microeconomic conditions in that nation (Faber and Hesen, 2004). According with Arundel and Kabla (1998), the propensity rate to patent is higher in large firms. In general, large companies present a higher intensity of R&D expenditure and also a higher propensity to patent. Probably because these companies have similar patenting strategies, organisational cultures to promote innovation, large budget, similar access to the same national research departments and in general manage the risk of innovation with a portfolio of projects that implies large budgets.

The economic structure of a nation affects the amount of successful innovations developed by firms. This structure is reflected in the technology input and size distribution of firms and in the degree of innovation orientation among firms of a nation.
A methodology to measure innovation in EU through the NIS

(Faber and Hesen, 2004). The successful introduction of product innovations also depends on several macroeconomic factors that shape the prevailing market conditions (Faber and Hesen, 2004). Geroski and Walters (1995) conducted a study in the UK with data from 1948 to 1983 and concluded that there exists a proportional relationship between the level of innovation and the level of economic activity. Furman et al. (2002) suggest that innovation is stimulated by local demand for more sophisticated products and that customers are sensitive to quality. A domestic exigent and sophisticated demand encourages domestic firms to offer technological products and increases their efforts to develop new products or services.

Associated to external factors that influence innovation, it is possible to identify other macroeconomic factors, such as openness to international trade, increase of domestic competition, demand for differentiated products, the size of the domestic market and the availability of resources for innovation (Furman et al., 2002). Cooperation between institutions is another factor that enables innovation by promoting the share of R&D costs and risks (Nunes et al., 2013; Spanos, 2012).

2.4.2 Institutional conditions imposed by the national infrastructure for innovation

Additionally to other economic conditions, there are some others conditions identified in national innovation infrastructure that are needed to promote innovation activities carried out by a nation during a year (or in other period of time), for example, the innovation inputs, such as, the availability of financial resources and human resources. The government regulations, such as, tax system and business taxation, affects innovation activities, that’s why some countries have regulations allowing tax benefits for innovative companies (Faber and Hesen, 2004).

Faber and Hesen (2004) also include the importance of highly qualified human resources and the public expenditure on R&D, factors widely discussed in this research. In summary, there are four dependent institutional conditions of government policies that foster the number of patents and the sales of innovative products, in particular, the availability of venture capital, tax system, the availability of human capital and public R&D expenditures.

2.4.3 Contextual conditions

In the contextual conditions it is taken into account the entrepreneurial climate, which is indicated by the degree of entrepreneurship within the labour population, it is the entrepreneurial climate prevailing within a nation, this means that if a nation is able to provide its citizens with conditions to be entrepreneurs, this will be reflected in the SNI (Faber and Hesen, 2004).

3 Empirical study

This section describes the methodology of this research beginning with the description of the national innovation system (NIS) and the operationalisation of the variables used in the empirical study.
3.1 Variables

This work is supported in the research developed by Faber and Hesen (2004) that studied only the manufacturing sector but this research study also includes the services sector, therefore it is necessary to adjust some variables.

The choice to replicate the research developed by Faber and Hesen (2004) is justified for the quality of the results obtained, the confidence of applying a tested model and also the chance to include other sectors in the study.

In order to explain the results of innovation processes the following input, process and output variables, were identified and selected, at firm level and at the level of the national innovation infrastructure. Moreover, the causal effects expected from the input and process variables in the output variables are given, as they are expected to be positive (+), negative (−) or indeterminate (+/−).

The following information (Table 1) is adapted from the work of Faber and Hesen (2004), having, in the national economy structure, been replaced the relative presence of SMEs by the intensity of foreign direct investment, this is due to the fact that data was not available for all countries and because literature suggests that foreign direct investment is a key factor to promote innovation (Lall and Narula, 2004; Kemeny, 2010; Lipsey, 2006; Fu and Gong, 2011).

Table 1 Variables and expected effects

<table>
<thead>
<tr>
<th>Type of variables</th>
<th>Variable to analyse</th>
<th>Expected effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output variables</td>
<td>Patents granted</td>
<td>+</td>
</tr>
<tr>
<td>at firm level</td>
<td>Sales of innovative products</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Difficulties encountered during the innovation process</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>Use of external information sources</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Cooperation in R&amp;D</td>
<td>−</td>
</tr>
<tr>
<td>Process variables</td>
<td>Private spending on R&amp;D</td>
<td>+</td>
</tr>
<tr>
<td>at firm level</td>
<td>Total expenditure on innovation</td>
<td>+</td>
</tr>
<tr>
<td>Input variables</td>
<td>Technological input distribution</td>
<td>+</td>
</tr>
<tr>
<td>at firm level</td>
<td>Intensity of foreign direct investment</td>
<td>+</td>
</tr>
<tr>
<td>Input variables</td>
<td>The orientation of companies towards innovation</td>
<td>+</td>
</tr>
<tr>
<td>in the level of</td>
<td>Size of the national economy</td>
<td>+</td>
</tr>
<tr>
<td>the national</td>
<td>Level of economic prosperity (+/−)</td>
<td>(+/−)</td>
</tr>
<tr>
<td>innovation</td>
<td>Openness of the national economy</td>
<td>(+/−)</td>
</tr>
<tr>
<td>infrastructure</td>
<td>Availability of venture capital</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Level of firms taxation</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>The average number of years of education of the human</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>resources</td>
<td></td>
</tr>
<tr>
<td>Contextual</td>
<td>Degree of entrepreneurship of the labour force</td>
<td>+</td>
</tr>
<tr>
<td>conditions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In order to control the eventual effects caused by size differences between countries, all variables, except the size of the national economy, the level of economic prosperity and the average number of years of education of the workforce will be expressed in proportional units.

Table 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>Acronym</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patents</td>
<td>PATENT</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Innovative sales</td>
<td>VEND.INOV</td>
<td>Cis III and Cis IV (Eurostat)</td>
</tr>
<tr>
<td>Private R&amp;D</td>
<td>R.D_PRIV</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Total R&amp;D</td>
<td>R.D.TOT</td>
<td>Cis III and Cis IV (Eurostat)</td>
</tr>
<tr>
<td>Information sources</td>
<td>FONT.INFO</td>
<td>Cis III and Cis IV (Eurostat)</td>
</tr>
<tr>
<td>Cooperation for R&amp;D</td>
<td>COOP</td>
<td>Cis III and Cis IV (Eurostat)</td>
</tr>
<tr>
<td>Difficulties during R&amp;D</td>
<td>DIFIC</td>
<td>Cis III and Cis IV (Eurostat)</td>
</tr>
<tr>
<td>Added value by medium and high tech sectors</td>
<td>GVA.MED.HIGH</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Foreign direct investment intensity</td>
<td>FDI</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Innovative firms</td>
<td>EMP.INOV</td>
<td>Cis III e Cis IV (Eurostat)</td>
</tr>
<tr>
<td>GDP</td>
<td>PIB</td>
<td>Eurostat</td>
</tr>
<tr>
<td>GDPpc</td>
<td>PIBpc</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Economy openness</td>
<td>ABERT.ECON</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Venture capital</td>
<td>VENT.CAP</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Taxation</td>
<td>IMP</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Education</td>
<td>EDUC</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Public R&amp;D</td>
<td>R.D.PUB</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Entrepreneurship</td>
<td>EMPREEND</td>
<td>Global entrepreneurship monitor</td>
</tr>
</tbody>
</table>

The model considers variables to 11 European countries to the years 2000 and 2004 using statistical micro data from CIS III and IV. The countries present in the study are: Germany (2000 and 2004), Belgium (2000 and 2004), Denmark (2000 and 2004), Spain (2000 to 2004), Finland (2000), France (2000 and 2004), Greece (2004), Italy (2000 and 2004), Portugal (2000 and 2004), UK (2000) and Sweden (2004). Although we use CIS firms micro data, we have chosen to use all patent applications, measured as the number of patent applications to the EPO by all organisations and citizens residing in a given country. This choice is justified to capture the entire patenting dynamic of the countries, including cooperation to innovation, because some public institutions might patent inventions that occur in collaboration projects with firms and some individuals might patent inventions that will then be use by firms.

The variables used in this study based on the work of Faber and Hesen (2004) and Hesen (2001) are:
1 Innovations within and between firms:
   a Input variables comprising:
      • private expenditure on R&D, measured as the percentage of the GDP spent on R&D (European Union, 2012)
      • total spending on innovation (R&D and others), which are measured by the percentage of total turnover of enterprises spent on innovation – adapted from Hesen (2001) and Faber and Hesen (2004).
   b Process (input) variables, comprising:
      • sources of information available to firms, measured as the percentage of companies that contacted various sources of information – adapted from Hesen (2001), Faber and Hesen (2004) and the European Union (2010)
      • cooperation between firms on R&D, measured as the percentage of innovative firms that cooperate with another firm on R&D – adapted from Hesen (2001), Faber and Hesen (2004) and the European Union (2010)
      • difficulties encountered by firms during innovation projects, measured as the percentage of companies that have faced such difficulties – adapted from Hesen (2001) and Faber and Hesen (2004).
   c Output variables, comprising:
      • patent applications, measured as the number of patent applications to the EPO by all organisations and citizens residing in a given country, per million inhabitants of that nation (European Union, 2010)
      • sales of product innovations by firms, measured as the percentage of total sales of firms realised from sales of new and substantially improved products (European Union, 2010; Faber and Hesen, 2004).

2 National innovation infrastructure, represented only by input variables:
   a Economic conditions, including:
      • The structure of the economy, represented by three indicators:
         2.1 technological input distribution over industrial sectors, measured as the percentage of total value added by medium and high-tech firms – adapted from Hesen (2001) and Faber and Hesen (2004)
         2.2 the intensity of foreign direct investment measured as the sum of the percentages of input and output of foreign direct investment to GDP (EIU, 2007)
         2.3 the relative presence of innovative firms within the national economy, measured as the percentage of innovative firms – adapted from Hesen (2001) and Faber and Hesen (2004).
      • The prevailing market conditions, which are represented by three indicators:
         2.4 the size of the economy, measured as the GDP in billions of Euros (Faber and Hesen, 2004)
         2.5 the level of economic prosperity, which is measured by the GDP per capita in Euros (Faber and Hesen, 2004)
2.6 the openness of the economy, measured as 
\[ \frac{(\text{Exports} + \text{Imports})}{\text{GDP}} \] (Fagerberg and Srholec, 2008).

b Institutional conditions including:
- the possibilities to finance innovative projects, measured by the percentage of venture capital to GDP (Hesen, 2001; Faber and Hesen, 2004)
- the fiscal climate wherein firms operate, measured as the percentage of firms taxes in the GDP (Faber and Hesen, 2004)
- the availability of human resources to carrying out innovation activities, measured by the average number of years of education of the labour force, adapted from Faber and Hesen (2004) and from Bassanini and Scarpetta (2001)
- public expenditures on R&D, measured as their percentage to GDP (European Union, 2010; Faber and Hesen, 2004)
- Entrepreneurship, measured as the percentage of the population between 18 and 64 years old who is the owner or manager of a business – adapted from Hesen (2001) and Faber and Hesen (2004). Table 2 presents the variables previously mentioned.

3.2 Methodological presentation

Based on of the research presented by Faber and Hesen (2004) and after the introduction of the appropriate adjustments in the data, this study performed two multiple linear regressions:

- the first multiple linear regression uses as dependent variable the patents and all others variables are considered as independent variables
- the second multiple linear regression uses innovative sales as the dependent variable and all others are considered as independent variables.

3.2.1 Analysis of patents variable as dependent variable

The hypotheses to be tested, considering as dependent variable the number of patents, are:

Hypothesis 1 Input variables influence positively the number of patents.
Hypothesis 1.1 Process variables influence positively the number of patents.
Hypothesis 1.2 Output variables influence positively the number of patents.
Hypothesis 1.3 Economic conditions influence positively the number of patents.
Hypothesis 1.4 Institutional conditions influence positively the number of patents.

The goal is to build the best multiple linear regression models with the dependent variable patents. A quality model is the one that with the fewest possible independent variables explains most of the variation in the dependent variable patents. In the work of Faber and Hesen (2004), the multiple linear regression model was initially built considering all variables, after performing similar attempts it was found that the results
were not satisfactory. The signs of the regression coefficients were not the expected in most situations and none of the independent variables showed individually significance to the model, and even in some cases, the hypotheses test to the overall significance of the model showed values of the p-value superiors to any acceptable level of significance.

Given the small sample size \( n = 18 \) and the high number of independent variables in relation to this dimension, and after the results mentioned above we chose the technique of stepwise variable selection (step by step). In this type of regression the most important variables are selected as well as the order in which they enter into the equation, resulting in the best possible model for predicting the dependent variable. The results of the model are presented in Table 3.

<table>
<thead>
<tr>
<th>Model</th>
<th>( R )</th>
<th>R-square</th>
<th>Adjusted R-square</th>
<th>Std. error of the estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.931</td>
<td>.866</td>
<td>.858</td>
<td>36.42912</td>
</tr>
<tr>
<td>2</td>
<td>.960</td>
<td>.921</td>
<td>.910</td>
<td>28.91651</td>
</tr>
<tr>
<td>3</td>
<td>.977</td>
<td>.955</td>
<td>.945</td>
<td>22.57604</td>
</tr>
</tbody>
</table>

After fitting a linear model using multiple regressions analysis we need to determine how well the model fits the data. In Table 3, we may find the results of the R-squared and the adjusted R-squared statistics.

R-squared, also known as the coefficient of multiple determinations is a statistical measure of how close the data are to the fitted regression model. As we can see in Table 3, the model number 3 presents the best value, 0.955, what led us to say that the model explains approximately 96% of the variability of the response data around its mean.

Whenever we use multiple regressions and try several models by changing the set of independent variables it is crucial to analyse the adjusted R-squared. This statistic compares the explanatory power of regression models that contain different numbers of predictors and increases only if the new term included improves the model.

Looking at Table 3, we may conclude that along with R-squared the adjusted R-squared has the highest value for model number 3, being 0.945 confirming that this model is the better one.

The F-test for overall significance, also known as ANOVA F-test, that tests the null hypothesis ‘all of the slopes in the model are equal to zero’ versus the alternative hypothesis ‘at least one slope does not equal zero’, presented, for all the three models, a p-value equals to zero, lesser that any significance level defined, showing that we would reject the null hypothesis, concluding that at least one of the slopes differs significantly from zero.

In Table 4, we can analyse the value of the estimated regression coefficients and also the test result to the individual significance of each independent variable in the model. Once again we only interpret the values corresponding to model 3.
We begin by rewriting the estimated model considering the values obtained for each coefficient:

\[
E[\text{Patents}_i] = -154.95 + 88.49R_D_PRIV_i + 203.16R_D_PUB_i + 3.06\text{EMP_INOV}_i; \ i = 1, \ldots, 18
\]

The values presented in the previous equation explain how the independent variables included in the model contribute to the variation in the dependent variable (patents).

In this case, we are interested in comparing the contribution of each one of the independent variables, so we will use the beta values that correspond to the standardised regression coefficients. Looking at the column of the beta values, we can easily understand which the highest value is and thus which variable contributes more to the prediction of the dependent variable.

The variable that contributes most to the prediction of patents is R&D funded by privates with a standardised coefficient of 0.673, then percentage of innovative firms (0.299) and lastly R&D financed by the public sector (0.204).

Analysing, we can conclude that all independent variables are individually significant for a significance level of 1%, as all values are well below 0.01.

Based on the statistical analysis we can also conclude that Hypothesis 1 (the input variables positively influence the number of patents), is partially validated, since the variable R&D funded by privates positively influences the number of patents. The Hypothesis 1.1 (process variables positively influence the number of patents), is not validated. The Hypothesis 1.2 (the output variables positively influence the number of patents), is not validated. The Hypothesis 1.3 (economic conditions positively influence the number of patents), is partially validated, since the variable percentage of innovative firms positively influences the number of patents. The Hypothesis 1.4 (institutional conditions positively influence the number of patents), is partially validated, since the variable R&D financed by the public sector positively influences the number of patents.
Economically and according to the literature, the three variables of the final model have the expected influence in the dependent variable patents, meaning that all positively influence the number of patents. Moreover, all final variables are linked to R&D, since the percentage of innovative firms also increases if more companies invest in R&D, being this factor an excellent indicator of companies’ investment in the development of innovations (Arundel, 2006).

Thus, the positive proportional relationship between R&D and number of patents is confirmed (Artz et al., 2010), since the R&D efforts contribute to innovation in enterprises (Li, Chen and Shapiro 2009).

3.2.2 Analysis of innovative sales variable as dependent variable
The hypotheses to be tested, considering as dependent variable the innovative sales, are:

Hypothesis 2 Input variables influence positively the innovative sales.
Hypothesis 2.1 Process variables influence positively the innovative sales.
Hypothesis 2.2 Output variables influence positively the innovative sales.
Hypothesis 2.3 Economic conditions influence positively the innovative sales.
Hypothesis 2.4 Institutional conditions influence positively innovative sales.

The use of innovative sales variable as dependent variable did not allow building a model with significance, so we chose not to present the results obtained by the regressions performed because none of the hypotheses above could be tested or validated.

4 Conclusions
In the literature review were identified the benefits of innovation for economic growth and productivity, enhancing the undeniable contributions of innovation to the economy of countries (Martin and Nguyen-Thi, 2010; Pedersen, 1977; Hasan and Tucci, 2010; Apergis et al., 2008; Crépon et al., 1998; Markatou, 2013).

It is not surprising, therefore, that the EU has increased investments in R&D and has several programs to support and promote innovation. There are several ways to promote and foster innovation; one is the inputs of innovation, for example, human capital, entrepreneurship and venture capital, among others. Moreover, the results of these factors are the outputs (inventions our innovations), for example, patents (precursor of innovation), innovative sales, product and process innovations, marketing and organisational innovations (Organisation for Economic Co-operation and Development, 2010a).

This study concludes that the most important variables for innovative performance (measured as number of patents) are the input variables, economic conditions and institutional conditions, with the following factors, respectively, private R&D, percentage of innovative firms and public R&D, the estimated model has a 95.5% R² using three independent variables, while the model of Faber and Hesen (2004) has an R² of 96.1% using nine independent variables.

Thus, although the model of this study explains a little less of the variation of the patents, the model quality is superior, since it uses fewer variables than the model of
Faber and Hesen (2004), for a sample of 18, compared to a sample of 22 used by the authors. This is true because many authors consider that for a model with nine independent variables, to ensure a quality model, a sample higher than one hundred is necessary (Stevens, 1996; Tabachnick and Fidell, 2001), moreover, the variables present in this study satisfy the conditions of normality, something that we cannot confirm in relation to Faber and Hesen (2004) model.

We can conclude that there is a strong linear relationship between R&D and patenting (Griliches, 1990), since the three independent variables are, somehow, related to R&D, because even the percentage of innovative firms increases if more companies invest in R&D. This relationship between R&D and patents is consistent with the state of the art (Artz et al., 2010; Arundel, 2006; Bloch and Graversen, 2008; Li et al., 2009), and with the objectives of European policy to increase the share of R&D to GDP (Arundel, 2006).

The estimated model partially validates the Hypothesis 1 (the input variables positively influence the number of patents), the Hypothesis 1.3 (economic conditions positively influence the number of patents) and the Hypothesis 1.4 (institutional conditions positively influence the number of patents). This validation happens but, surprisingly, uses only the three variables mentioned above.

As already mentioned, in the state of the art, there is a conviction of a proportional relationship between the number of patents and the spending on R&D, having this relationship been confirmed in this study, but this does not exclude the possibility of the other study variables can be important for this or for any of the other identified outputs, something that has to be proven in future scientific work even because, some of these outputs, such as process and organisational innovations arise, usually, without investment in R&D. Furthermore, the industrial sector is technologically active in seeking innovations (patents) to protect their new products, for this to happen it is necessary that the various inputs mentioned exist. By including in the model the entire economy, we may have missed this significance relationship, since innovations in services arise from ideas and creativity and can almost immediately be put into practice if the human resources with these qualities exist. Another factor to take into account is that in the services sector, that dominates most of the developed economies, it is not possible to patent, ideas cannot be protected (Arundel, 2006).

The main conclusion that we can draw from this work and its main contribution to economic research and for companies, is that private R&D is the engine of patents, since this variable explained 86.6% of the variation in the number of patents thus, in addition to continuing to fund public R&D, the EU should invest more in stimulating private R&D, with tax policies and other benefits, to promote investment in innovation, since, as previously stated, patents are precursors of innovation. Similarly, it is expected that this work can foster among Portuguese companies the need to invest in R&D as a way to increase sales (Mohnen et al., 2006), productivity (Crépon et al., 1998) and competitiveness (Gust-Bardon, 2014).

Thus, the main contributions of this work to management are the following:

1. the EU should continue to promote policies to support innovation in companies
2. the EU must ‘innovate’, finding new ways to encourage private initiative in the field of innovation seeking, thereby, to increase the number of innovative enterprises which, as we saw, is one of the main contributors to the creation of patents and, consequently, innovations
the EU should continue and, if possible, increase public funding for innovation, as this is one of the ‘engines’ of innovation.

According to the state of the art, many of the variables present in the study positively influence innovation, but their results according to the present academic work, are marginal.

The innovative performance of the EU is almost entirely explained by the three variables mentioned above, but this does not exclude the possibility that some of them help leverage these three important variables, because, for example, there is a strong correlation between the partial GDPpc and number of patents being, presumably, safe to say that a EU country with a high per capita GDP is a more technologically developed country with a stronger propensity to patent (Faber and Hesen, 2004). For example, it is also safe to assume that if there is an increase in FDI flows, part of that flow will be ‘diverted’ to R&D activities and if business cooperation in innovation activities increases it will also increases the investments in R&D and, consequently, increases the number of innovative companies (Fagerberg and Godinho, 2005). On the other hand, countries can only increase their investments in R&D if they have qualified human resources to work in this sector (Huang et al., 2010).

Thus, although statistically insignificant for the final model, several of these variables are nonetheless, very important to enhance the innovative performance of EU and should continue to be studied to better understand their effects on innovation activities because exists a strong correlation between several of the independent variables, on the other hand, the final three variables of the model only explain 35.3% of the $R^2$, and it is only with the overlay of all the variables, in particular the shared variance, that the $R^2$ increases to 95.5%.

Thus, public policies cannot only focus on the validated hypotheses (input variables, economic conditions and institutional conditions), or just in R&D, but also have to promote education, entrepreneurship and all the other variables mentioned in this study because they are fundamental to innovation or for the creation of conditions that enable innovation to occur, not only in industrial sector but in the whole economy.

As to the objectives of this study, it can be concluded that they were partially achieved. The general objective of identifying the factors that determine the innovative performance of countries, measured as patents, allowed identifying three statistically significant factors, namely, private R&D, the percentage of innovative firms and public R&D.

As for specific goals, many factors that contribute to innovation (all inputs mentioned at work) were identified, and all outputs resulting from innovation have been identified. The correlation of the variables in the study identified the relationships between them and it was concluded that the most important ones for explaining the variation of the patents are, private R&D which explains 86.6% of the variation in the number of patents, the percentage of innovative firms which explains 5.5% and public R&D which explains 3.4%.

A limitation of this study, that it is important to mention, arises from the fact that we work with a reduce sample due, in part, to the lack of some statistical data for some countries.

It would be interesting that future research aimed at understanding how the other outputs of innovation described in this paper come up: product innovations, process innovations and marketing innovations/organisational.
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References


Freeman, C. and Soete, L. (1997) *The Economics of Industrial Innovation*, Taylor & Francis Ltd., England.


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Kemeny, T. (2010) Does Foreign Direct Investment Drive Technological Upgrading?, Lewis Center for Regional Policy Studies, University of California, Los Angeles, USA.


Notes

1 Vide (Rodriguez, 2000).