The aim of the article is the comparison of the number of the patent applications to EPO and R&D expenditure in select countries between 1990 and 2011. The data has been compiled from the Eurostat database. The analysis of R&D expenditures and patent applications showed that Sweden was at the top position, followed by Germany, Finland and Denmark. The further places are for the Netherlands, Austria and Luxembourg. At the end of the ranking are Bulgaria, Romania, Slovakia, Lithuania, Greece and Poland.

**Keywords:** Patent, EPO, patent activity, R&D expenditure, European Union

The growing importance of knowledge and information in industrial processes is a significant feature of contemporary economy. The ability to create new knowledge and to transform it into new products, services and technologies, result in competitive advantage for companies and the whole economy. There is no innovation without the spread of new techniques and technology, and these are the carriers of economic growth.

Innovation is the result of R&D activity and legal protection shields it from unfair competition. Research and development and appropriate legal protection play a key role in creation of qualitative competitive advantage and are significant determinants of economic growth. As it is known from the systemic models of innovation, many other determinants besides R&D activities are involved in accounting for innovation (or for patenting, considering that patenting is closely associated with innovation).

This study analyses two factors of innovation, namely, expenditure on R&D and the number of patents. The article focuses on the answers to the following questions:

What is the number of patent applications and R&D expenditure in the EU countries?

Which countries are distinguished in terms of patent activity and the amount of R&D expenditure?

How can countries with similar number of patent applications and activity expenditures on R&D be grouped?

**Purpose and Methodology**

The aim of the paper is the comparison of the number of patent applications at the EPO and R&D expenditure in select countries between 1990 and 2011. The data source is the Eurostat database and the focus is on the European Union countries.

To illustrate similarities and differences between patent applications and R&D expenditures in the European Union countries, Ward’s hierarchical cluster analysis has been applied. This hierarchical cluster analysis method is suitable for quantitative variables and does not require *a priori* definition of the clusters number. The method begins from the presumption that every unit (object) is a separate cluster, after which the individual objects that are most similar to each other, are linked step-by-step into groups and the process continued until only one cluster made up of all the observations is left.

The Ward’s hierarchical cluster analysis is viewed as effective because objects in the same cluster are homogeneous whereas there is heterogeneity across clusters. This method is different from other methods because it utilizes an analysis of variance approach to evaluate the distances between clusters. Cluster membership is estimated by calculating the total number of squared deviations from the mean of a group. The rules for fusion is that it should create the smallest possible increase in the error sum of squares.

In the first model, sixteen variables from the period 1990-2010 have been used to characterize patent applications (2011 data was not available). For the second classification, eleven variables related to R&D expenditure level per capita over the period 1990-2011
have been applied. It means that 33 variables have been used in the whole system. The statistical analysis was re-executed with Excel and Statistic 10.

**Classification of Countries on the Basis of Number of Patent Applications**

The European Patent Office (EPO) grants European patents for the Contracting States to the European Patent Convention. The EPO offers a single patent grant procedure though not a single enforcement system. The patents granted are not European Union patents or even Europe-wide patents, but simply a bundle of national patents. EPO allows protection of an invention in 38 members states of Convention pointed out in the application of the applicant.

It has been observed that during 1990-2010, the disparities in patent applications to the EPO have fluctuated. In the beginning of the described period, the coefficient of variation for patent applications to the EPO in the mentioned countries was 101.6 per cent, ten years later it was 117.6 per cent, and in 2010 it was 107.6 per cent. If the coefficient of variation for any agglomeration is higher than 65 per cent, such a data set is considered as having great variability. The coefficient of variation values show that patent applications to the EPO are highly diversified.

Patenting activity in the world picked up from the year 1990 onwards. The number of patents increased significantly. The growth in patenting activities observed in most patent offices however, seems to be due to increased internationalization of patents rather than to an explosion in innovations.

The cluster analysis with respect to patent applications to the EPO resulted in formation of five groups of countries. The dendrogram was cut at the linkage distance 250, based on the graph of node distance in relation to the node steps. The first distinguishable abrupt increase of agglomeration distance was observed at this linkage distance.

The dendrogram analysis (Fig. 1) in terms of patent applications to the EPO may lead to the conclusion that this criterion determines cluster separation. The countries gathered on the left side of the tree have a larger number of patent applications to the EPO compared to the ones on the right side.

The first cluster (on the right) has more number of countries, i.e. Bulgaria, Romania, Slovakia, Lithuania, Poland, Greece, Portugal, Latvia, Malta, Cyprus, Hungary, Czech Republic, Estonia, Spain and Slovenia (Fig. 1). That cluster shows the countries with the lowest patent applications per one million inhabitants. In the eight, first mentioned countries (upto Latvia), the

![Fig. 1 –Number of patent applications at the EPO during 1990-2010: Country clusters](source: Author’s own calculations based on the Eurostat)
The number of patent applications per one million inhabitants in 2010 ranged from 1.6 to 11.7. The number of patent applications per one million inhabitants in the other countries varied between 10.4 and 38.2, whereas in Slovenia it was 80.8 (Fig. 2). Slovenia, although with a much larger number of patents, was in the first group probably due to the relatively low patenting activity of the country in the nineties and early 21st century. Between 2004 and 2010, there was an increase in the number of patents (except Bulgaria -0.29) but to a different extent across the countries in this cluster: it increased by 0.08 times in Malta and 0.11 in Spain and 4.84 times in Estonia.

It is worth mentioning that the unitary patent protection has been accepted under the EU’s legislative procedure. Once the Act is enforced, it is anticipated that it would reduce the competitiveness of companies in the countries with low patent activity. The beneficiaries of the unitary patent protection will be mostly from the countries that are highly advanced in technology, where business enterprises get a great number of patents. In the countries with a low patent activity, the economic development will be restricted by property rights. Their domestic business enterprises will have to take into account pleas in infringement of patent rights, because – contrary to the current situation – the patent descriptions will not be accessible in their native languages.

Low patent activity in the former Eastern Block has many causes, the first being the historical circumstances. Centrally planned economy was operated there for a long time. A second reason could be the personality of the entrepreneurs themselves. It appears that entrepreneurs would be willing to patent their inventions if they knew what the patent offers. This inference calls for a robust policy initiative to enhance awareness about patenting in enterprises.

Thirdly, since the businesses are facing financial difficulties in conducting business, patenting is felt to only result in additional costs. Increased political activity in the form of an active patent policy is therefore necessary in these countries.

The 2nd cluster comprises Italy, Ireland and the United Kingdom (Fig. 1). In 2010, in the mentioned countries, the number of patents applications per one million inhabitants varied between 73.6 patents in Italy to over 79.1 patents in Ireland (Fig. 2). The most significant growth in patent applications from 2004 to
2010 was in Ireland at 0.16 per one million inhabitants. However, in the same period of time, both Italy (-0.07) and the United Kingdom (-0.17) saw a decline in the number of patent applications per one million inhabitants, which can be explained by the recent economic crisis in the years 2008 and 2009.

The 3rd cluster covers the Belgium and France (Fig. 1). In 2010, the number of patent applications per one million inhabitants varied from 130.2 patents per one million in Belgium to 135.3 patents in France (Fig. 2). The growth factor in 2010 vis-à-vis 2004 was -0.11 in Belgium and 0.01 in France.

The 4th cluster includes Luxembourg, Austria, Denmark and Netherlands (Fig. 1). In 2010, the number of patent applications per one million inhabitants varied between 165.0 patents in Luxembourg to more than 243.8 patents in Denmark (Fig. 2). The number of patent applications per one million inhabitants between 2010 and 2004 decreased in Luxembourg by a growth factor of -0.35 and in the Netherlands by -0.13 in the Netherlands. In contrast, the growth factor increased in Austria (0.06) and Denmark (0.19).

The 5th cluster has three countries, Finland, Germany and Sweden (Fig. 1). The number of patent applications per one million inhabitants in 2010 accounted for 218.1 patents applications in Finland up to 308.3 patents in Sweden. The growth factors in 2010 compared to 2004 were -0.17 in Finland and -0.04 in Germany, but 0.24 in Sweden. Frietsch, Neuhausler, Rothengatter analysis indicates that impact of the economic crisis is especially visible in countries that are very active in the USA. Countries like Germany do not show direct crisis effects. From the priority year 2008 onwards, however, a decreasing trend can be observed for this country also.10

Classification of Countries on the Basis of R&D Expenditures

Research and development activity is a priority activity in order to gain quality as a competitive advantage. Research and development is an important key to achieve success in any industry as India’s leading drug companies realized; that they could not be global players without important R&D capabilities.11

According to OECD, research and experimental development is creative work undertaken on a methodical basis in order to increase the stock of knowledge, containing knowledge of man, society and culture and the use of this stock of knowledge to create new applications.12 The level of R&D expenditures in individual countries is diversified, although the tendency to minimize the disparities can be observed. The coefficient of variation for R&D expenditures between the countries being analysed was 90.27 per cent in 2011, whereas it had been 98.87 per cent in 2004 and 105.62 per cent in 1995. The coefficient of variation shows that R&D expenditures are highly diversified.

The cluster analysis with respect to the level of R&D expenditures resulted in the formation of four groups of countries (clusters). The cutting point of the dendrogram (using Ward’s method) was the node at the linkage distance 2715, basing on the graph of node distance in relation to the node steps. At this linkage distance, the first distinguishable abrupt increase of agglomeration distance has been observed.

The dendrogram analysis (Fig. 3) in terms of expenditures on R & D activity depicts the cluster separation in terms of expenditure level. The countries gathered on the left side of the tree have higher levels of R&D expenditure than the ones at the right side.

The 1st cluster is the largest and contains 10 countries having the lowest R&D expenditures - Bulgaria, Romania, Latvia, Poland, Slovakia, Lithuania, Cyprus, Malta, Greece and Hungary (Fig. 3). In 2011, the R&D expenditures per capita varied from 29 Euros in Bulgaria to over 121 Euros per Hungary inhabitant (Fig. 4). The growth factors in 2011 as compared to 2004 increased from 1.3 in Greece to 3.1 in Latvia.

In both the Lisbon Strategy as well as the Europe Strategy 2020, it was resolved that the R&D expenditures, as a percentage of GDP, should attain the value of 3 per cent. The gross domestic expenditure on R & D as a percentage of GDP is called the R&D intensity. R&D intensity is used as an indicator of an economy’s relative degree of investment in generating new knowledge. The R&D intensity went up 0.5 per cent in Cyprus and Romania to 1.2 per cent in Hungary in 2011.

The 2nd cluster includes Portugal, Czech Republic, Estonia, Spain, Slovenia and Italy (Fig. 3). In 2011, the R&D expenditures were up from 240 Euros per capita in the Portugal to more than 436 Euros per capita in Slovenia (Fig. 4). In all the countries, a growth in R&D expenditures was observed although to a varying degree; it went up from 1.2 in Italy to 4.6 in Estonia. The R&D intensity was 1.3 per cent in Italy and 2.5 per cent in Slovenia.
Fig. 3 — Investment in R & D activities per inhabitant (in Euro) between 1995-2011: Country clusters

Source: Author’s own calculations based on Eurostat

Fig. 4 – Expenditure in Euro per capita on R & D activities in the years 1990, 2004 and 2011

Source: Author’s own calculations based on Eurostat
The 3rd cluster contains the following countries: the United Kingdom, Belgium, France, the Netherlands, Ireland, Germany and Austria (Fig. 3). The R&D expenditures per capita in these countries were relatively high. The expenditures in these countries fluctuated between 496 and over 983 Euros per inhabitant (Fig. 4). The highest expenditure was in Germany and Austria and the lowest in the United Kingdom. The expenditures between 2011 and 2004 increased by various factors: from 1.0 in the United Kingdom to 1.5 in Austria. The R&D intensity was lowest at 1.7 per cent in Ireland and went up to 2.8 per cent in Germany.

The 4th cluster consists of Luxembourg, Finland, Denmark and Sweden (Fig. 3). These countries have the highest R&D expenditures per inhabitant: 1188 Euros in Luxembourg to approximately 1389 Euros in Sweden (Fig. 4). Between 2004 and 2011, the increase in R&D intensity was different across the countries in this cluster: it increased by 1.2 times in Sweden and Luxembourg and 1.5 times in Denmark. R&D intensity varied from about 3.1 per cent of GDP in Denmark to almost 3.8 per cent of GDP in Finland. In Luxembourg, it was only 1.4 per cent of GDP. Luxembourg seems to be unique here – although this country had a relatively low R&D investment, it was high in absolute terms and this country was near the top with respect to R&D spending per capita. This can be ascribed to its extremely high GDP compared to the population. The very small population of Luxembourg makes this country not representative for EU average.

The new EU members, which joined the bloc during the fifth enlargement wave (2004-2007), realized the necessity of rapid growth in R&D expenditures. The inequalities in expenditure were quickly made up by Estonia. In this country, the growth factor (2004 to 2011) was the largest. Significant growth factors were observed also in Latvia (over 3.1), Romania, Bulgaria, Slovakia, Poland, Slovenia, Lithuania and the Czech Republic (above 2.0 in all these countries). In Cyprus, Malta and Hungary the growth dynamic was lower - this factor did not exceed 1.9 for these countries.

Only few countries meet the standards of Lisbon Strategy Europe 2020 Strategy in terms of percentage of expenditures on R&D vis-à-vis GDP. Radical changes in the innovation policy of many countries are necessary to fulfill standards of EU. It will be difficult to achieve the competitive position of say, the United States or Japan without increasing the activity of many members of the EU. In subsequent years, the EU will have to face competition not only from the United States and Japan, but also from the rapidly rising economies of Far Eastern countries (India, China and South Korea). The European Commission documents indicate that the total R&D investment in the EU increased by 50 per cent between 1995 and 2008. This shows significant lower growth rate compared to that in other parts of the world: 855 per cent in China, 145 per cent in the other BRICS countries (Brazil, Russia, India and South Africa), 75 per cent in developed Asian economies (South Korea, Singapore, Japan, Taiwan) and almost 100 per cent in the rest of the world. As an outcome, the EU’s share of world R&D expenditure decreased from 29 per cent in 1995 to about 24 per cent in 2008 (ref. 14).

The study analysed overall volume of spending on R&D. The structure of this expenditure is also an important element. Observations show that countries with greater involvement of the business sector in financing of R&D activities achieve favourable results in terms of progressive innovation.

The EU documents emphasize that investing in R&D will not be effective if they are not invested in a first rate research and innovation system - a system that is capable of transforming ideas into innovation and spurring development and deployment of technologies for society and industry. A more efficient research and innovation system means achieving the best possible output from invested input. A more effective system means generating more relevant outcomes for the society and economy. It is noted that the objectives of effectiveness and efficiency should therefore be actively implemented and must cover the whole innovation cycle. There is no perfect model for innovation. Its specific configuration will not be optimal if it is not adjusted to the industrial, cultural and social setting at a regional and national level. This indicates that many features of a system can be moved from one setting to another with small modifications, especially from other countries with similar patterns. The country profiles presented in a research conducted by the European Commission, show that some countries dominate more in science and technology given the same level of public expenditures. In some countries, the challenge for efficiency begins at the reforms needed to achieve scientific perfection. Growing
expenditures have raised levels of perfection in science and technology in many countries, but the degree of progress may still be below the EU average. For other countries, the principal challenge is to trigger rapid growth of innovative entrepreneurs and international competitiveness by disseminating knowledge. A good innovation system should have an effect on international competitive advantage and on the trade harmony of products and services.\textsuperscript{14,16}

**Conclusion**

The issues presented above indicate considerable diversification at the level of R&D expenditures in different countries and the number of patent applications (Table 1).

The analysis of per capita R&D expenditure and of patent applications per one million of the country inhabitants filed in the EPO showed that the top position in the ranking was taken by Sweden, followed by Germany, Finland and Denmark. The further places were occupied by the Netherlands, Austria and Luxembourg. High R&D expenditures and great number of patent applications reflect on strong economy development in these countries. At the end of the ranking are Bulgaria, Romania, Slovakia, Lithuania, Greece and Poland. It is observed that the countries with higher expenditures on R&D have a larger number of patents applications. Other studies have shown, that R&D spending was positively related to patents.\textsuperscript{17-19} The countries occupying the last positions in the rankings are mainly from Central and Eastern Europe, Greece and Spain. Countries with not so good results should observe nations with better innovative capabilities and strive to achieve that level by adapting their innovation system specifically to their country. Policy makers would be wise to undertake a comparative analysis (either formally or informally depending on the resources they possess) of the relative profits in entrepreneurship, technology commercialization and economic benefits earned from the investment of public budget toward R&D in the cluster ranked immediately above the cluster their own countries are grouped. Policy makers could also evaluate the macroeconomic advantage that accrues to the countries in the next higher ranked clusters as an effect of increased patent activity.

Polarization in R&D and patent activities has been indicated in several reports.\textsuperscript{14,20} Capital expenditure in R&D is concentrated in some parts of the European Union. Half of the total R&D expenditure in the EU27 countries is generated by about 60 NUTS2 (Nomenclature of Territorial Units for Statistics) regions, i.e. one fifth of the regions in the EU. Half of all the remaining regions contribute to only 6 per cent of the total R&D expenditure in EU.\textsuperscript{14} In the Innovation Union Scoreboard Report, countries are divided into four groups according to the level of innovation: innovation leaders, innovation followers, moderate innovators and modest innovators.\textsuperscript{20} Portions of the current work corroborate the division among countries in the above mentioned documents.

Furthermore, it indicates that the relationship between patents and R&D is not simple. The evolution of patent activity does not necessarily follow R&D personnel ideas. Nothing exemplifies this better than the fact that patent activity is concentrated in the business sector, even as similar proportions of R&D personnel are employed in the business sector and the higher education sector. A big portion of R&D personnel are also employed in the government sector.\textsuperscript{21}

However, it has to be noted that the volume of patent applications may not be a good indicator of R&D strengths of the member states. The number of patents depends on the nature of industries in an individual country. Not all inventions are patented and patenting activity is highly dependent on the technological area. Various industries require various forms of incentives (and also different forms of IP) for improving innovation capabilities. The fact that some researchers/research within the member states may have been seeking protection only within their national jurisdiction, due to market constraints/financial constraints, should not be forgotten. The studies, in addition, indicate that not every invention is patented.\textsuperscript{22} Rassenfosse and Pottelsbergh de la Potterie indicate that two components play a significant role in the R&D - patent relationship, as verified by the impact of several policies, including education, intellectual property and science and technology policies. It is important in many countries,
to create awareness of intellectual property protection. Studies in Canada have shown that respondents had good knowledge of patent rights. However, they had insufficient knowledge of what does not constitute a public disclosure and duration of the public disclosure grace period. Further education of the stakeholders in obtaining valid patent rights for commercialization is recommended. The cause of low activity in the field of industrial property protection in some countries (e.g. Poland) is due to a low level of awareness of the necessity of legal protection of material goods. Entrepreneurs are yet to realize the role that patent protection plays in the functioning of enterprises.

References


2. Hierarchical clustering is a technique of cluster analysis, strategies for which are typically of two types: agglomerative - this is a ‘bottom up’ approach (each case starts in its own cluster, and pairs of clusters are merged as one moves up the hierarchy) and divisive - this is a ‘top down’ approach (all cases start in one cluster, and split recursively as one moves down the hierarchy). The effects of hierarchical clustering are presented graphically in a dendrogram.


5. The coefficient of variation (CV) illustrates the ratio of the standard deviation to the mean. It is a helpful statistic for equating the degree of variation from one data series to another, even if the means differ drastically from each other. CV is a normalized measure of dispersion of a frequency distribution or probability distribution. It is presented as a percentage.


