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# INFLUENCE OF INTELLECTUAL CAPITAL ON INNOVATION ACTIVITY

## Abstract

The primary aim of this paper was to indicate the existing similarities and differences in the innovative activity of European countries depending on intellectually capital involvement.

Number of staff employed in the R&D sector is one of the main factors having an influence on the states' innovative activity measured for individual countries in the number of patent application filed on their territory by native inventors.

It's assumed that innovative activity is dependent on expenditures on R&D activity, number of persons generating the gross domestic product as well as the capabilities for knowledge processing, and therefore on scientific research staff resource. Because in this study analyses of Poland's innovative activity were to be made, a cross-sectional time analysis including OECD European members was used. In econometric analyses concerning Central and East European countries researchers more and more often reach out for data relating to the group of countries with similar development trends, similar past and ambitions for the future.As the research's methods the space-time model based on the unbalanced space-time sample was used.

**Key words:** Human capital, Models with Panel Data, Innovation and R&D

## Introduction

A topic that more and more often appears in world literature is the development of innovation as the main driving force of economic growth. Descriptions often concern numerous issues related to a widely understood innovative policy of a country, however, almost each of them contains the issue of quantification – how to measure the increase in innovation. There are certain attempts to measure the share of new and modernized products in the overall output, to measure the value of investments related to the creation of new solutions or the number of people involved in innovative activities. The primary aim of this paper was to indicate the existing similarities and differences in the innovative activity of European countries depending on intellectually capital involvement. In this paper innovation shall be understood as the number of patents submitted by the residents of a given country. In comparison to the above-mentioned solutions, this solution has a few unquestionable advantages:

- figures concerning patents submitted by residents prove their potential – they are not tantamount to the number of granted patents, but only show the number of solutions accepted in the first phase of submission,
- data concerning the number of submitted patents are characterised by comparability with many countries and terminology that has been the same for years,
- time series of data are much more regular and longer than in the case of the above mentioned shares of new and modernised products,

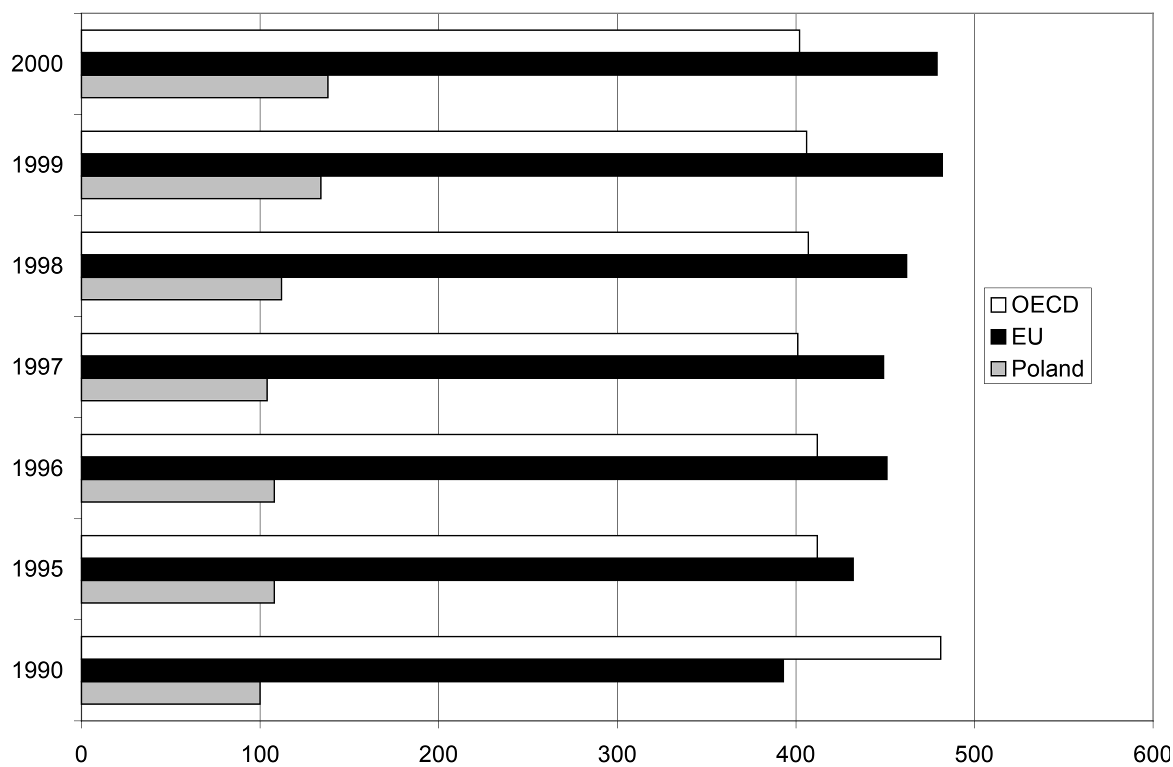
- in contrast with the above-mentioned category, repeatability of solutions among submitted patents is very little,
- application of an index in the form of submitted patents shows the potential of creators representing the intellectual potential of a given country.

Another – already mentioned – issue is availability of data enabling economic analysis. In the case of countries that in the last years have undergone transformation aimed at redirecting centrally planed economy to something similar to free market economy, time series of economic data are usually short. They at most enable static analysis and exclude any prognoses or simulations. A kind of solution is to use space and time models that in their structure assume making use of space and time tests. Inference on the basis of models obtained in this way is possible only when the used objects are characterised by a similar course of the examined phenomenon and the shape of relations with respect to the explanatory variables. Using decomposition of an absolute term in these models makes it possible to draw individual conclusions for separate objects, whereas assessments of parameters show general relations for the whole test.

**Innovative activity determinants**

In comparing scientific potential a very important role is played not only by expenditure on R&D activities, but above all on the activeness of the sphere of research. This activeness is more and more often characterised by (apart from the already-mentioned: number of patents or licences) the number of academic publications compared to a given part of population. This first of all shows the level of involvement on the part scientists in basic as well as applied studies, and consequently the power of intellectual capital of a given country.

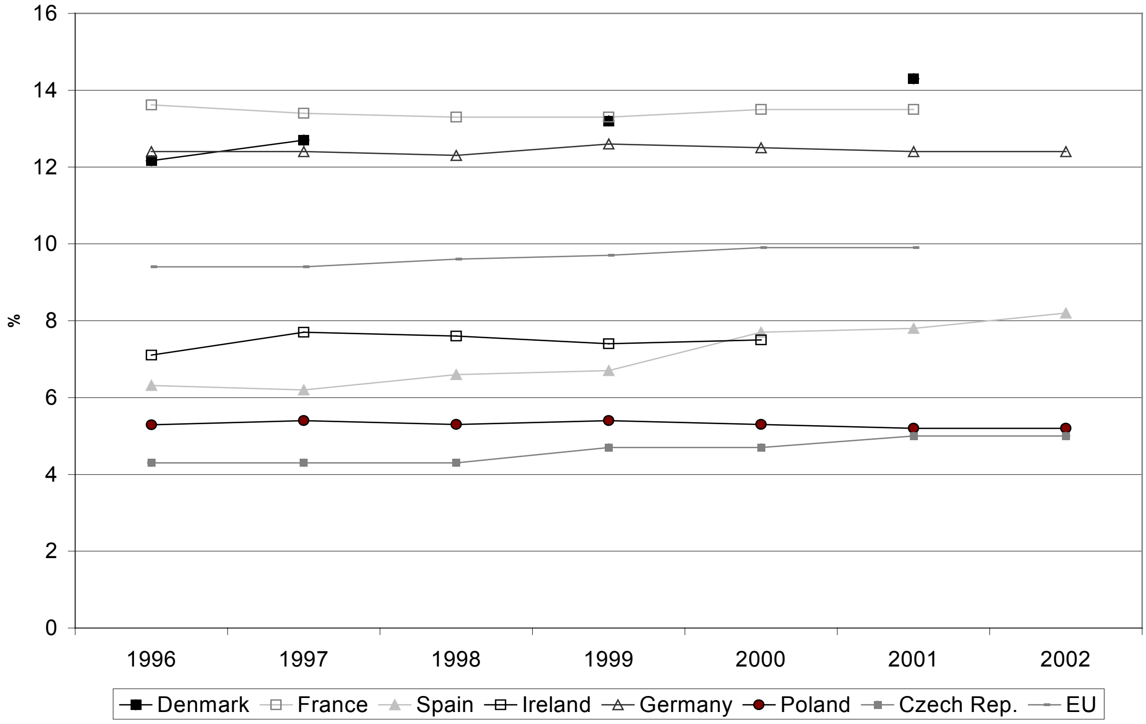
Chart 1. Number of academic publications per million people in Poland, the European Union and OECD between 1990 and 2000




Source: Own compilation on the basis: (OECD 2002, s.317)

The number of publications in Poland is three times lower than the average in the European Union (Chart 1). This situation is caused by a kind of isolation that took place in the period before the transformation, which to a large extent limited scientific development. Also the command system connected with central planning caused in some cases the development of uneconomical and unprospective fields of science, related only to political aims. A low number of Polish publications is also connected with relatively lower employment in the R&D sector in comparison with other countries, and, what's worse, with lower involvement in the development of employment in this sector. Countries being members of the European Union, characterised by similar rates are marked by a dynamic development of employment in R&D in the last few years.

Chart 2. Staff employed in the R&D sector per thousand of professionally active people (in full-time equivalents)

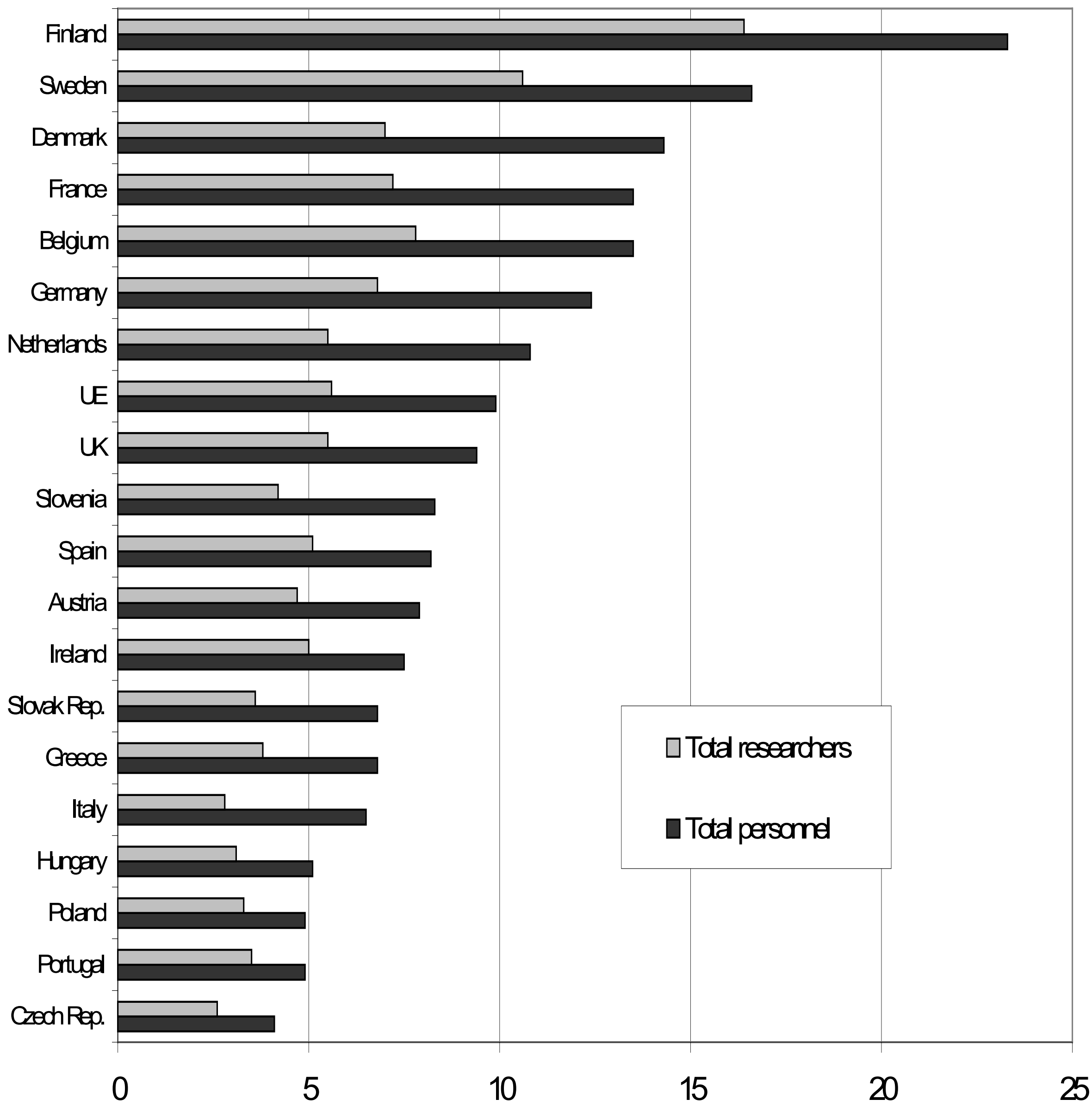



Source: Own compilation on the basis: (OECD 2004, s. 22)

Countries with the highest expenditure on the R&D sphere are also characterised by the highest employment rate in this area (Chart 2). This employment rate corresponds to demand related to using funds for R&D activities and handling very extensive scientific base operating in the enterprise sector. It needs to be noticed that in the case of countries with the highest expenditure on R&D activities, most of it comes from this very sector. However, as far as the structure of employment within the sector is concerned (Chart 3), it is similar for all countries.

A study concerning the relation between the total number of people employed in the R&D sector and the number of researchers proved the existence of a strong correlation. The value of Pearson's correlation coefficient calculated for these data amounts to 0.94. On this basis it may be concluded that an efficient employment structure in the R&D sector should be characterised by such shares of researchers in the overall number of people employed in the R&D sector. This share in the case of the above-mentioned countries amounts to about 60%.

Chart 3. People employed in the R&D sector per 1000 of professionally active people in 2002 (or the last known) in countries being members of the European Union in full-time equivalents.

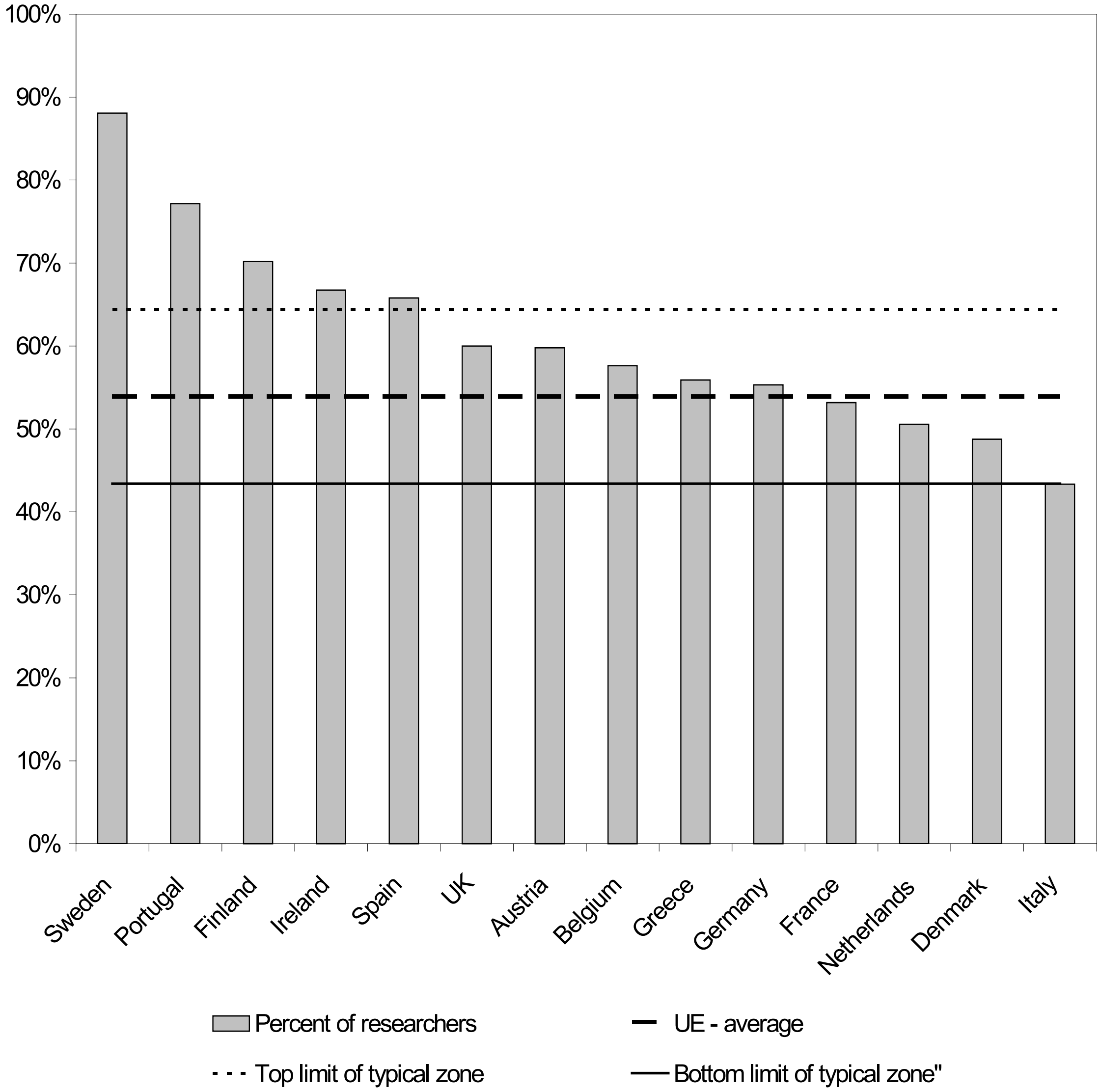



Source: Own compilation on the basis: (OECD 2004, s. 21-22)

It is worth stressing that staff not involved in research also plays an important role in the whole innovation process. It is them that influence the efficiency of research units, the flow of information and many other organisational issues, without which the functioning of these units would be very difficult.

The share of workers directly involved in science in relation to the overall number of workers employed in the R&D sector in the countries of Central and East Europe is almost identical with the European Union and amounts to 57%. However, it is much less diversified in countries of Central and East Europe than in the EU, or even homogeneous. The lowest percentage of research workers in this sector is in Russia – 50%, and Poland may boast about the highest level of employment of highly qualified researchers in this sector – 67%. When analysing the relation between expenditure on R&D activities and the structure of employment, it is impossible to find common trends in policies of these countries

Chart 4. Number of research workers with reference to overall staff in countries being members of the European Union in 2001 or the last known




Source: Own compilation on the basis: (GUS 2002, s. 98)

Research workers in the European Union constitute on average 60% of all employees in this sector and the level of their employment in the R&D sector reaches the maximum of 80% in the case of Portugal and the minimum of 45% in the case of the Netherlands (Chart 4). Taking into account the results of Portugal concerning innovation, it needs to be stated that there is a shortage of non-research workers. Maybe this situation, causing the above-mentioned problems, makes it impossible to use the scientific potential fully.

The above discussion depicts in a simplified way the “standards” existing in the European Union related to pro-innovation policy. Despite certain differences resulting from geopolitical as well as historical and economic conditions, it may be noticed that all countries being members of the European Union have many common features.

**Model structure assumptions**

In the presented study a key issue was the measurement innovation in Poland. Because of the above-mentioned technical problems the space and time model was proposed to illustrate the development of innovation in Poland in relation to other European countries. The model is only a single equation simplification of the >>>> model presented on the conference with extension of data series in some cases up to 24 observations and increase in the number of objects up to 26. The test is a non-balanced test – individual objects are represented in it by data series of various length.

Additionally, while building a database, there appeared problems typical in such a situation. Some data were collected with two-year frequency or even less often, in some cases there was a lack of single information. Most gaps within the series were eliminated by means of interpolation using the interval method. Moreover, to achieve better comparability, the indicated data were related to the number the employed.

In this study year-old data were applied. The data selection criteria for estimated models were based on the following principles:

- the size of the prime series has to exceed six observations (an application of good statistical tests for $n < 5$ is rather difficult ; moreover, an additional sixth observation may be helpful in case of corrections made in order to eliminate the random components autocorrelation),
- estimation of missing values at the end of series but for not more than two cycles is allowed, provided that information on the previous ten cycles is available and applied,
- estimation of missing information in case of data with two-year frequency is allowed.

In case of series with the length exceeding 10 cycles that are characterized by large variation, any missing values from the final period were determined by means of the harmonic weight method or, in case of any clear trend present, by the use of the trend function. Individual missing data in particular years were eliminated using the interval method.

While constructing the model it was assumed, that:

- Innovative activity for individual countries manifests itself in the number of patent application filed on their territory by native inventors.
- Patent activity is dependent on expenditures on R&D activity, the level of potential innovative capacity defined by scientific-technical knowledge transfer and expressed in the number of patent applications filed on territory of a given country by foreign investors as well as on the capabilities for knowledge processing, and therefore on scientific research staff resources.
- The dynamics of patent activity development in different countries is similar as far as its growth rate is concerned, but its "starting point" is different for economies with different degrees of development. This results from the economic potential and capacity for absorption of external scientific-technical knowledge.

The following form of dynamic space-time model, with decomposition of absolute term has been proposed:

$$Pem_{it} = \alpha_0 + \alpha_1 Pem_{it-1} + \alpha_2 Gem_{it} + \alpha_3 Gem_{it-1} + \alpha_4 Nem_{it-1} + \alpha_5 Rem_{it} + \alpha_6 Rem_{it-1} +$$
$$+ z_1 at + z_2 de + z_3 dk + z_4 es + z_5 fr + z_6 ie + z_7 nl + z_8 se + z_9 uk$$

$Pem_{it}$ – number of patent applications filed by residents in terms of one thousand total employment in a given period t for a given country i,
$Pem_{it-1}$ – number of patent applications filed by residents in terms of one thousand total employment in a given period t –1 for a given country i,
$Gem_{it}$ – gross expenses on R&D activity in a given period t for i-th country in terms of one

thousand total employment,
$Gem_{it-1}$ – gross expenses on R&D activity in a given period t for i-th country in terms of one thousand total employment,
$Nem_{it-1}$ - number of patent applications filed by non-residents in terms of one thousand total employment in a given period t -1 for a given country i,
$Rem_{it}$ –R&D personnel in terms of thousand total employment in a given period t for i-th country,
$Rem_{it-1}$ –R&D personnel in terms of thousand total employment in a given period t -1 for i-th country,
Dummy variable after decomposition of absolute term for all countries and untypical: *at* – Austria, *de* – Germany, *dk* – Denmark, *es* – Spain, *fr* – France, *ie* – Ireland, *nl* – Netherlands, *se* – Sweden, *uk*- United Kingdom.

Table 1. Estimation values of model parameters

| Parameter | Variable | Parameter estimate | Parameter error | T - statistics | P-value |
|---|---|---|---|---|---|
| $\alpha_1$ | *Gem* | 0,381 | 0,093 | 4,086 | 0,000 |
| $\alpha_2$ | *Rem* | 0,012 | 0,006 | 2,189 | 0,029 |
| $\alpha_3$ | *Gem1* | -0,420 | 0,089 | -4,740 | 0,000 |
| $\alpha_4$ | *Rem1* | -0,010 | 0,005 | -1,836 | 0,067 |
| $\alpha_5$ | *Pem1* | 0,810 | 0,021 | 39,131 | 0,000 |
| $\alpha_6$ | *Nem1* | -0,008 | 0,004 | -1,843 | 0,066 |
| $z_1$ | *at* | 0,073 | 0,031 | 2,320 | 0,021 |
| $z_2$ | *de* | 3,479 | 0,274 | 12,718 | 0,000 |
| $z_3$ | *dk* | 0,429 | 0,070 | 6,167 | 0,000 |
| $z_4$ | *es* | 0,105 | 0,044 | 2,395 | 0,017 |
| $z_5$ | *fr* | 0,621 | 0,098 | 6,316 | 0,000 |
| $z_6$ | *ir* | 1,003 | 0,114 | 8,834 | 0,000 |
| $z_7$ | *nl* | 0,164 | 0,049 | 3,355 | 0,001 |
| $z_8$ | *se* | 0,149 | 0,036 | 4,176 | 0,000 |
| $z_9$ | *uk* | 0,127 | 0,042 | 3,022 | 0,003 |
| $\alpha_0$ | absolute term | 0,014 | 0,012 | 1,235 | 0,218 |

Source: own calculation.

The presented results (Table 1) prove most of the adopted assumptions. The obtained dynamic model is characterised by a good match to the empirical data – reaching the level of 0.998. Moreover, thanks to using delayed variables, the phenomenon of autocorrelation was eliminated (DW = 1.84; $r_1$ = 0.057). All variables are characterised by significance on the level not exceeding 0.07.

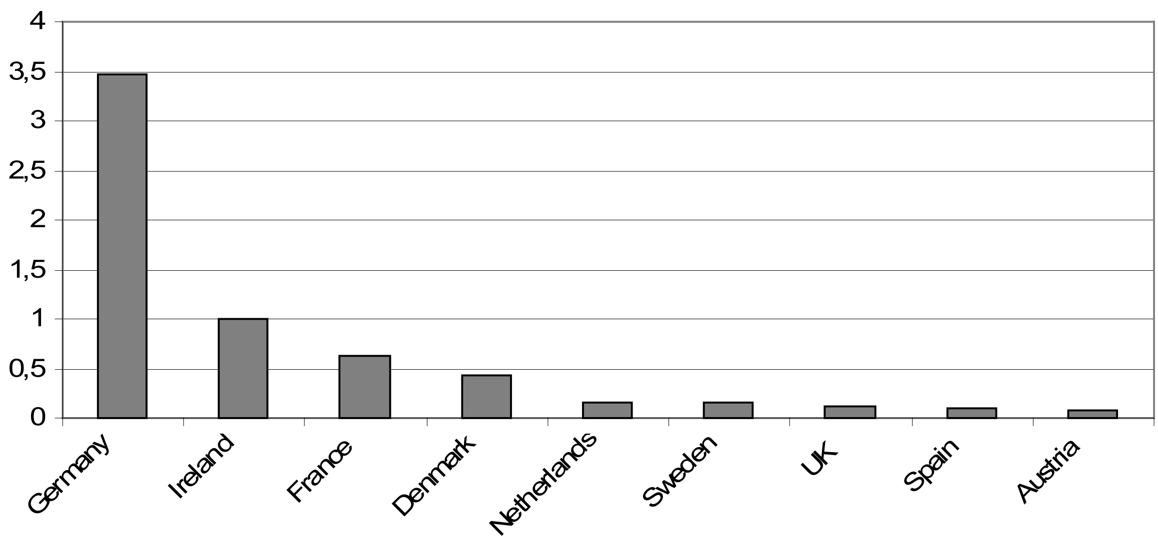
Taking into consideration the detailed results, we may prove a significant influence of expenditure on R&D activities on the development of innovation. An increase in this expenditure of one unit causes an increase in activeness of 0.381 of a unit, assuming stability of the remaining factors. When analysing the influence of expenditure from the previous period, we may observe a negative nature of the relationship. However, it arises due to the structure of the model – the assumed stability of the remaining elements. Thinking logically, if expenditure in t period is constant, and in t-2 period it increases, the expenditure in t period relatively decreases over time, which in fact may cause a decrease in activeness. To dispel ambiguities, we checked a model containing, instead of static and delayed variables, only increases of these variables, and the values of parameters turned out to have a positive direction. Therefore, we may state that mathematical assumptions in this case comply with economy theory.

As far as further interpretations are concerned, we may speak of a very significant positive influence of the amassed experience and intellectual capital, which manifests itself in innovative activeness from the previous period. The value of parameter – 0.81 – with its undeniable significance, proves these speculations. Potential innovation receptivity has an opposite influence on activeness. The number of patents submitted by non-residents in a given area in the past period causes that native inventiveness is displaced by foreign inventiveness. Obviously, a considerable portion of activeness is regulated by purely market behaviours. When analysing expenditure on R&D activity or the place of execution of research, it becomes quite clear that the burden of implementing innovations is shifted from the government to the industrial sphere. In highly developed countries, the majority of R&D staff is employed in the industrial sector. This sector is able - in the best possible way - to make use of its intellectual potential for purposes directly related to production.

The last variable representing R&D staff is characterised by similar properties as these previously analysed ones. Its influence on an increase in innovation activeness is little as far as numbers are concerned – 0.012 – however, this factor is worth noticing. What makes it significant is its value in relation to an error. It needs to be remembered that this is an index of staff share in the number of the employed, so its unitary increase actually shows an increase on the level of 1 per mille.

The presented interpretations of model parameters simply prove the previously adopted assumptions concerning the relationship between intellectual potential of a country and its application in the innovation creation process. The presented time and space model also makes it possible to verify differences in the level of innovation activeness in individual countries.

Chart 5. Differences in the level of absolute term values of individual states




Source: Own calculation

Chart 5 points out a distinct advantage of the level of innovation activeness in the case of Germany. This level is a result of the former policy of this country as far as implementation of innovation is concerned. In principle, all countries included in the graph are characterised by a higher than average level of innovation activeness. To a large extent it results from making use of human capital. All of the presented countries are characterised by a high employment level in the R&D sector – and especially by a high employment level of researchers. For example, in "the weakest" from the mentioned countries – Austria – the number of employed researchers is the same as the number of all employees in this sector in Poland.

## Conclusions

The estimated model pointed out the influence of human capital on the development of innovation activeness, which in this paper is measured by the number of people employed in the R&D sector. In spite of a relatively constant number of researchers in the 90's, the results of their activity had increasing character. On one hand, it is connected with increased financial resources allocated to R&D activity and more technologically advanced equipment being purchased and used, on the other hand, however, as it has already been stressed earlier - innovations have cumulative character. Younger researchers can use the knowledge and experience achieved and handed down by their predecessors. One should certainly mention the imitation process, which in case of common consumer goods not infrequently replaces research, using only information on the market demand.

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