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DETERMINANTS OF THE NUMBER OF PATENTS IN THE CZECH REPUBLIC

DETERMINANTY POČTU PATENTŮ V ČESKÉ REPUBLICE

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Abstract: *Knowledge represents an important national, regional or firm asset that creates a source of competitive advantages. However, there are no standard methods that are able to determine the extent to which an economy is based on knowledge and to measure the outputs of knowledge economy. Economists had already begun to use the number of patents to investigate an entire range of relationships, for example, to analyse their relationship to company size, investment and innovation activities. Therefore, the aim of this paper is to analyse the influence of selected determinants of the knowledge economy that affect its output (the number of patents in the Czech regions). The analysis is realized by using own original multiple linear regression model. Data for the analyses were obtained from the Czech Statistical Office's databases between the years 2007-2011. The results confirm the importance of the human factor during the process of patent creation. The role of increasing expenditure on research and development activities was proven to be insignificant in the Czech regions. In the Czech Republic, there is a lack of studies measuring knowledge economy and its determinants. Therefore, we provide an initial analysis of determinants influencing knowledge economy.*

Keywords: *Patents, human capital, analysis, Czech regions, multivariate regression model*

JEL Classification*: O11, O13.*

Introduction

Currently, competitiveness is a topic that is frequently discussed and dealt with in economic analysis. This applies not only to individual companies or sectors but also to regions by whatever definition. Competitiveness is an entity's ability to be successful in a competitive environment so that its goals are achieved to the greatest possible extent (and in the most effective way; Prokop, Stejskal, Kuvikova, 2017). In fact, competitiveness is considered to be one of the most significant determinants of economic development; gradual increase of this determinant results to the fulfilment of objectives of regional policy and to the growth of welfare, quality of life and long-term economic development (Amin, 1999).

Knowledge and the ability to transform it into innovation are becoming the foundation for individual regional and national economic systems. These often try to support the creation, acquisition and transfer of knowledge – both financially and non-financially. In this way, the economy often becomes dependent or based on knowledge. Regarding each government's limited financial possibilities, the question arises as to the effectiveness of such attempts (and support for such attempts) to create and develop a knowledge economy (Stejskal, Merickova, Prokop, 2016). There are no standard, generally recognized methods that are able to determine to what degree an economy is based on knowledge (Kitson, Martin, Tyler, 2004). Various studies argue about whether economies' knowledge base is measurable or how to measure a knowledge economy's outputs, which are necessary for different types of economic analysis (Leydesdorff, Dolfsma, Van der Panne (2006). In many analyses, renowned authors have used an indicator based on the number of patent applications and registered patents in the given country (Acs, Anselin, Varga, 2002; Hudec, Prochadzkova, 2013; WB, 2016). In the Czech Republic, there are no studies evaluating to what degree Czech economy is based on knowledge and the determinants of the knowledge economy.

Therefore, the goal of this paper is to provide an initial analysis and evaluate the influence of selected determinants of the knowledge economy on the selected output – i.e., the number of patents in the Czech Republic's regions – and provide some practical implications for policy makers not only in the Czech Republic. The analysis will be conducted by using a multivariate linear regression model constructed by the authors using data for the Czech regions from 2007—2011 provided by the Czech Statistical Office (period of time is dependent on the period for which the complete data sets are available). The remainder of this paper is divided in the following way. The first two sections are focused on the problematic of the knowledge economy and its measurement, not only in general but also focusing on the use of patents as an indicator of knowledge processes. The third section describes the methodology and analysis results. The last section comprises the research's concluding evaluations and provides practical implications for policy makers.

1 Patents as an Indicator of Knowledge Processes

Using patent statistics as an indicator of technological activity has been used in Western countries since the 1960's. At that time, economists had already begun to use the number of patents to investigate an entire range of relationships, for example, to analyse their relationship to

- company size;
- investment activities; and
- the degree and trend of innovators' activities (Pavitt, 1985).

In 1984, Pakes and Griliches (1984) followed up on this and proved in their studies that patents can be a suitable tool for measuring the differences in knowledge advancement between individual companies. Subsequently, Jaffe (1986) also emphasized the influence of spillover effects between neighbouring companies; he stated that the R&D activities of companies with neighbours that focus largely on research and development produce many more patents per dollar.

Patents, including subsequent patents (patents that have developed from the original patents), provide a very useful way to measure innovation performance, because patent data can be used not only to monitor the activities of competitive companies, but also to create an evaluative system of research and development performance within companies and, not least, to help identify current trends in technology development (Katila, 2000). For these reasons, patents are often used in various studies as an indicator for measuring the output of innovation activities (from the microeconomic perspective) or the knowledge economy (from the macro- or mezzo-economic perspective).

There are a number of studies that have analysed other component aspects within this problematic. For example, Agrawal and Henderson (2002) examined the extent to which patents can represent the size, direction and impact of knowledge effects from universities. Acs and Sanders (2012) tested the role of patents using an endogenous growth model and confirmed that companies using patent protection are more motivated to invest in research and development and to generate more new knowledge. Similarly, the positive influence of new knowledge on entrepreneurial activity, innovation activity and growth was also confirmed by this study. Bottazzi and Peri (2003) dealt with measuring companies' innovation output in regions by using the overall number of patents granted to manufacturers in the given fields. McAleer and Slottje (2005) arrived at a simple new method for measuring innovation called the Patent Success Ratio (PSR), which determines the ratio of successfully awarded patents to the overall number of patent applications. Acs et al. (2002) contributed to the discussion with a summary of the phases of the innovation process, for which he also lists a measurable indicator. This is

- the amount of the inputs into the patent process (indicator: expenditure on R&D);
- the intermediate output (indicator: the number of inventions that were patented); and
- the direct measurement of innovation outputs (indicator: sales revenues from the innovation's commercial use over a specific time period, for example).

From the preceding information, it can be concluded that patents represent a significant variable for measuring the output of the knowledge economy.

On the other hand, there are studies that criticize this means of measurement, primarily because not all innovations are patented. Naturally, it can only be speculated as to how many innovation outputs are patented and how many of these outputs are not. Fontana et al. (2013) posit the opinion that there are three types of reasons why inventors decide not to patent their outputs:

- it is not possible to patent the innovations – the inventor is convinced that it is not necessary to patent the given output;
- the innovation is patentable, but the innovator assumes that the inventive steps of his innovation processes are large enough to warrant a patent;
- the inventor decides not to patent their output, because they prefer to keep the given innovation secret.

Despite the above, it is still clear that the number of patents represents an important indicator of the knowledge economy's level and, consequently, of the innovation performance of a region's economic entities. Table 1 shows number of patent application to the Industrial Property Office of the Czech Republic by domestic applicants, number of patent applications to the European Patent Office (EPO) in EU 28 between 2007-2011 and Czech Republic's position in the global competitiveness rating between 2007-2012. From Table 1 we can see that the number of patents in the Czech Republic increased slightly, the situation in the EU28 has mostly downward trend.

Table 1: Number of patent applications in EU28 and the Czech Republic

	2007	2008	2009	2010	2011
Czech Rep.	711	710	788	869	782
EU 28	58 578	57 049	56 815	56 769	57 445
	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
Position of the Czech Republic in the global competitiveness rating	33	33	31	36	38

Note: number indicates the share of each Applicant by their belonging to the home state
Source: Author's own analysis using the sources from Czech Statistical Office and www.vyzkum.cz, WEF (2017), and Eurostat (2017)

It appears to be necessary to continue to investigate the factors that can be influenced by the public decisions of national or regional authorities. Three hypotheses were defined in order to achieve the paper's goals.

H1: The level of education of the population in the Czech Republic's regions has a positive influence on the number of patents registered by enterprises located in the Czech Republic's regions.

This hypothesis is derived from the assumption that increasing competitiveness is influenced by knowledge, which is primarily created and disseminated by institutions from the tertiary education sector and, consequently, an increasing number of individuals with tertiary education. Therefore, we test the influence of the growth of individuals having completed tertiary education on the number of patents registered by enterprises located in the Czech Republic's regions. The next hypothesis H2 originated in conjunction with this assumption.

H2: An increase in the number of employees in research and development in the Czech Republic's regions has a positive influence on patent creation for inventors located in these regions.

This hypothesis develops the previous assumption and deals with the significance of the human factor in practice, represented by equivalent of people in R&D (FTE - full-time equivalent), including research, technical and other staff. Good human resource management can certainly predetermine the future success of individual companies and, thus, regions. Moreover, Dakhli and De Clercq (2004) state that investment into the human capital of science and research workers represent a determinant of an increase in both productivity and competitiveness at the company level.

Financial support from public budgets is also considered significant; currently, this is very common in the Czech Republic and has been observed by a number of authors, for example Maroušek et al. (2014). Therefore, the influence of public support on patent creation in individual regions is tested in hypothesis H3.

H3: Increasing expenditures for supporting research and development in the Czech Republic's regions has a positive influence on the number of patent applications.

2 Methodology

Data for analysis was acquired from the Czech Statistical Office's database for the Czech Republic's NUTS3 regions from 2007—2011 and from the Analysis of the Existing State of Research, Development and Innovation in the Czech Republic. A total of 11 variables were chosen for analysis (one output, i.e., dependent, and ten input, i.e., independent); they are listed in Table 2. The variables are factors influencing the knowledge economy as used by the World Bank in the Knowledge Assessment Methodology (KAM). The knowledge economy indicators selected were subsequently used to compose regression models investigating their influence on patent creation in the Czech Republic's regions. The changes in variable values for 2007—2011 that were used in the analysis were calculated in percentages and are listed in Table 2, rounded off to the third decimal place.

For analysing the relationship between variables, multivariate linear regression models were used. These models were created for the purpose of investigating the relationship between one dependent variable (the predicated variable) y and independent variables (predictors) x_1, x_2, …, x_n. The dependent variable was represented by the number of patents granted by the Industrial Property Office of the Czech Republic (IPO) to domestic applicants between 2007 and 2011. The independent variables were created by aggregate values for the Czech Republic's individual regions and are also listed in Table 2.

Table 2: The Dataset

Region	PAT	GDP	ZAM	EXP	TECHi	VZOR	TERC	CENT	POD	TECHe	NEZ
PHA	0.485	0.108	-0.001	0.012	0.624	0.658	0.420	0.070	0.098	0.844	0.846
STC	-0.052	0.074	0.078	-0.018	0.837	0.489	0.738	0.296	0.060	0.867	0.665
JHC	2.500	0.046	0.161	0.214	0.334	0.434	0.214	0.143	0.151	-0.162	0.683
PLK	-0.396	0.067	0.124	1.246	-0.430	1.824	0.542	0.369	0.528	0.909	0.581
KVK	-1.000	0.087	0.456	0.597	-0.164	0.823	0.108	0.000	-0.479	0.293	0.344
ULK	11.000	0.098	0.017	0.133	-0.233	0.439	0.375	0.171	0.044	-0.413	0.180
LBK	0.429	0.043	0.226	0.418	-0.458	0.618	0.599	0.257	0.937	40.778	0.563
HKK	0.164	0.142	0.285	0.321	0.463	0.223	0.156	0.270	0.081	1.450	0.592
PAK	0.000	0.130	0.096	0.263	-0.757	0.146	0.381	0.270	0.296	0.924	0.555
VYS	-0.167	0.129	0.198	0.451	0.088	0.057	0.313	0.318	0.296	1.158	0.676
JHM	1.595	0.171	0.441	0.951	6.224	0.505	0.438	0.386	0.206	1.415	0.417
OLK	0.125	0.183	0.149	0.407	0.069	-0.195	0.302	0.206	-0.147	1.374	0.689
ZLK	0.886	0.152	0.153	0.226	-0.432	0.813	0.329	0.321	0.015	0.266	0.553
MSK	0.270	0.174	0.437	0.787	0.655	0.269	0.319	0.370	0.710	0.507	0.163

Note: PHA = Prague; STC = Central Bohemia; JHC = South Bohemia; PLK = Plzeň; KVK = Karlovy Vary; ULK = Ústí nad Labem; LBK= Liberec; HKK = Hradec Králové; PAK = Pardubice; VYS = Vysočina; JHM = South Moravia; OLK = Olomoucký; ZLK = Zlínský; MSK = Moravskoslezský; PAT = overall increase in patents granted to domestic applicants by the Industrial Property Office of the Cz. Rep.; GDP = GDP per capita; ZAM = the overall number of employees in R&D; EXP = overall expenditure on R&D conducted in the Cz. Rep.; TECHi = payments for importing technological service into the Cz. Rep.; VZOR = the overall increase in utility models granted by the Industrial Property Office of the Cz. Rep.; TERC = the number of individuals having completed tertiary education; CENT = the overall number of centers conducting R&D activities; POD = overall direct R&D support from the Cz. Republic's national budget (institutional and special-purpose; basic and applied research); TECHe = revenues from exporting technological services from the Cz. Rep.; NEZ = registered unemployment.

Source: Author's own analysis using the sources from Czech Statistical Office, WB (2016), and Tödtling, Lehner, Kaufmann (2009)

In general terms, the most frequently used multivariate linear regression model (e. g. Ernst, 2001; Hou, Lin, 2006; Hingley, Park, 2016) takes the following form (Vlachogianni et al., 2011; Wright, Coff, Moliterno, 2014):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \quad (1)$$

where:

y is the dependent variable;

$x_1, x_2, \ldots, x_n$ are the independent variables;

ε is the error term creating variability in the variable y that cannot be explained by the linear effects n of the independent variables;

$\beta_1, \beta_2 \ldots \beta_n$ are called regression parameters and represent the unknown constants that should be established (estimated) from the given data.

To assess the validity of the regression model (or a regression estimate) and to reflect the fraction of variation in the Y-values that are explained by the regression line, coefficient of determination R^2 is subsequently used. Coefficient of determination is defined as follows (Schneider, Hommel, Blettner, 2010):

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (2)$$

where:

n is the number of observations;

$\hat{y}_i$ is the estimated value of the dependent variable for the i^{th} observation, as computed with the regression equation;

y_i is the observed value of the dependent variable for the i^{th} observation;

$\bar{y}$ is the mean of all n observations of the dependent variable.

R^2 is the fraction of the overall variance that is explained. The closer the regression model's estimated values $\hat{y}_i$ lie to the observed values y_i, the nearer the coefficient of determination is to 1 and the more accurate the regression model is.

Before composing the analysis, verification whether the data were not correlated was conducted by using Spearman's test. After fulfilling the first prerequisite and dismissing the possibility of multicollinearity in the model, the analysis itself was conducted. Formula of the Spearman´s test has following general form:

$$r_s = 1 - \frac{6\sum d_i^2}{N^3 - N} \quad (3)$$

Spearman´s Coefficient measures the strength of the linear relationship between two variables. Values of each variable are rank-ordered from 1 to N, where N represents the number of pairs of values (the N cases of each variable are assigned the integer values from 1 to N inclusive and no two cases share the same value). Difference between ranks for each case is represented by d_i.

3 Results

During the course of the analysis, investigation was also focused on the knowledge economy indicators' influence and on further potential variables that could, according to the World Bank, be used as indicators for measuring the knowledge economy. Subsequently, an increase in GDP per capita and also registered unemployment were selected as given dependent variables. However, no significant results were attained for any of the models created. On the other hand, the model attained significant values for the dependent variable of patents.

The final regression model, whose values are listed in Table 3, records both the resulting set of knowledge economy indicators and the occurrence of a number of strong ties between the variables. The value of the correlation coefficient R of this model was measured at 0.981. The value of the coefficient of determination R^2 achieved a value of 0.963, and the value of the adjusted coefficient of determination was 0.880. The model's p-value amounted to 0.015. The result of the p-value demonstrated that the model is reliable at a level of significance of $p < 0.05$ and allowed for the rejection of the null hypothesis about the insignificance of this model. The model's quality was verified using the Breusch-Pagan test, whose value was 0.309. Therefore, the null hypothesis was not rejected and the data are homoscedastic.

Overall, 9 of the 10 selected indicators were used in the resulting model (independent input variables). Only the EXP variable was excluded from this model – because of its impact in creating insignificant results. The model detected the significant influence of a total of 4 of the 9 (44 %) knowledge economy indicators on the chosen dependent variable, i.e., the overall increase in patents awarded by the Czech IPO by domestic applicants. The most significant relationships were identified for the ZAM, NEZAM and TECHi variables. These variables were significant at a level of $p < 0.01$. Another significant result was recorded for the TERC variable, which was significant at a level of $p < 0.05$. The results indicate the human factor's strong influence in the patent creation process – both for the ZAM variable, representing the overall number of employees in R&D, and for the TERC variable, which denotes the number of individuals having completed tertiary education. However, the variables representing the provision of financial support and an overall increase in expenditure on research and development were proved to be entirely insignificant during the course of the analysis.

On the basis of the results listed above, it is possible to accept hypotheses H1 and H2. It was demonstrated that an increase in the number of individuals with tertiary education (TERC) as well as the number of employees at R&D workplaces positively influence the dependent variable and contribute to an increase in patent creation in Czech regions. However, hypothesis H3, which investigates the influence of expenditure and support for research and development, was rejected; a significant influence on the increase in granted patents was not seen for the Czech regions.

Table 3: The Resulting Model and Its Values

Variable	p	sd	t
ZAM	0.001***	3.454	-7.834
TERC	0.022**	3.165	-3.660
CENT	0.333	4.906	1.098
POD	0.416	1.558	-0.905
NEZAM	0.001***	1.772	-8.771
GDP	0.101	10.459	-2.119
VZOR	0.396	0.779	-0.949
TECHe	0.108	0.047	2.064
TECHi	0.007***	0.237	5.038

*Note: p = p-value; sd = standard error; t = t-statistic; ***significant at a significance level of p < 0.01; **significant at a significance level of p < 0.05*

Source: own research

During the course of analysis, it was demonstrated that neither the EXP (overall expenditure on R&D conducted in the Czech Republic) nor POD (overall direct R&D support from the national budget) variables influence the dependent variable. For the variables representing expenditure on R&D, only TECHi (payments for importing technological services into the Czech Republic) attained significant results. For this reason, H3 was rejected.

4 Discussion

The analysis results confirmed the significance of human (knowledge) resources when creating patents in the Czech Republic. The same results were confirmed by McAleer and Slottje (2005) or Clarysse and Wright (2014) and many others.

Hypotheses H1 and H2 were confirmed using the results. From the results of H1, the significance of an increase in education level is evident for the creation of patents in the Czech regions. Significant impact of higher education level can be seen in number of the patent in the Czech Republic (see table 1), and also in Sweden (Arvemo and Gråsjö (2014), in UK (Guerrero, Cunningham, Urbano, 2015). But it can not be argued that an increased proportion of university-educated people are directly proportional to the number of patents (the evidence from CEE states is in Prokop, Stejskal and Kuvikova, 2017).

It is therefore necessary to continue to support the development of universities and institutions of the tertiary education sector. This support should not be provided only to increase the number of these institutions, but also with the goal of preserving a certain standard of quality. Some scholars highlight the importance of new forms of collaboration. For example the national government in Italy decided to intensify the cooperation and the effectiveness of the university R&D activities by the "entrepreneurial univesity" concept application (Perkmann, Fini, 2013). Their studies show that this concept leads to enhance the successful commercialization of academic research. However, there are also some studies what show the inefficient effects of this collaboration (Banal-Estañol, Jofre-Bonet, Lawson, 2015).

However, the cooperation on patents is implemented in the firm even without the involvement of universities or R&D organizations (in-house or based on external cooperation with other firms). There are many studies that highlight the positive effects on the firms´ productivity (for example: Andries, Thorwarth, 2014). Some other studies proved that the location influence the innovation ability. The firms´ location in Science and Technology Parks or Business Incubators strengthen relationship between internal knowledge acquisition and collaboration (Montoro-Sánchez et al., 2011).

The results of H2 produce similar conclusions to that of H1. In this case, it is necessary to focus on an increase in the number of qualified workers in research and development in the Czech regions. Placing emphasis on the professional qualifications of employees in such positions represents an important condition for the success of this prerequisite. On the other hand, an increase in expenditures for supporting research and development did not influence the creation of patents in the Czech regions. For this reason, H3 was rejected. Ineffective use of expenses is a relatively topical subject. The Banal-Estañol, Jofre-Bonet, Lawson (2015) postulated the same results. Therefore, it is necessary to focus more on the problematic of expenditures for supporting research and development – not only across the Czech Republic as a whole, but also at the regional level.

5 Conclusions

In recent years, the role played by knowledge in the processes of creating innovation and increasing the competitiveness of individual companies and regions continues to be more frequently documented. However, insufficient relevant data presents a barrier to measuring the level of the knowledge economy. Therefore, patents emerge as a significant output that can be used to measure innovation performance in certain cases. The goal of this paper was to evaluate the influence of selected knowledge economy determinants that affect innovation output. It also proved to be necessary to investigate factors that could be influenced by the public decisions of national or regional authorities.

Following the results of this research, we provide some practical implications for policy makers (not only in the Czech Republic). It is clear, that human resources represent one of the most important determinants influencing knowledge economy and patent creation signals one form of growth in intangible knowledge capital, increases in the size of the science and engineering workforce that subsequently lead to firms´(or regional/national) growth (Powell, Snellman, 2004). It is supported by the significant results in previous section. Importance of determinants: (i) the overall number of employees in R&D and (ii) the number of individuals having completed tertiary education; confirms this assertion. Therefore, it is necessary to support education and research and development centres. On the other hand, it is not the rule, that increasing number of public subsidies and increasing number of employees/R&D centres leads only to better results. As it was shown, variables CENT (the overall number of centres conducting R&D activities) and POD (overall direct R&D support from the Czech Republic's national budget - institutional and special-purpose; basic and applied research) did not affect dependent variable – PAT: overall increase in patents granted to applicants by the Industrial Property Office of the Czech Republic. The similar results are emerged by Agrawal, Henderson (2002) or Hingley, Park, (2016). Therefore, policy makers should carefully decide which projects and centres they will support (from national or European funds) and which not.

For all these reasons, future research has been planned that will monitor the influence of R&D on the development of knowledge in regions – with respect to a longer time period in order to better record the effects of providing public support, because certain effects appear over a much longer time period. It is evident that not all inventions are created immediately after public support has been provided and that, in many cases, subsequent granting of patents can extend to a longer period of time. The researchers are also conscious of the current absence of resources from European budgets in terms of the analysis that has been conducted and therefore we plan their inclusion in the next investigation of this problematic. We also plan to analyse the situation of the Czech Republic in the European Research Area in conjunction with the Europe 2020 Strategy in the area of research and development to capture the effects and impact of key determinants of knowledge economy.

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