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TRENDS IN INNOVATION PERFORMANCE OF LEADING ECONOMIES IN THE EUROPEAN UNION

TRENDY V INOVAČNÍ VÝKONNOSTI EKONOMICKÝCH LEADERŮ ZEMÍ EVROPSKÉ UNIE

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Abstract:
Innovation activities play an important role in economic growth and can be considered as the engine of economies. This article presents the results of a study focused on indicators of innovation activities of selected European Union countries in direct link with two factors of economic growth. It is argued that a dependency between innovation activities and economy performance exists and the relationship of these two indicators is considered. The first part of the paper focuses on the theoretical approach in the field of study, and the second part describes the factors included in the calculations. The results are presented and discussed in the final part of the article.

Key words:
Innovation, innovation performance, patent applications, gross domestic product.

Abstrakt:
Inovační výkonnost hraje klíčovou roli v ekonomice země a lze ji označit za hlavní motor výkonnosti a ekonomického růstu. Předkládaná studie se zabývá problematikou inovační výkonnosti vybraných zemí Evropské unie v přímé souvislosti s výkonem ekonomiky daného státu a vzájemně porovnává dosažené výsledky a trendy jejich vývoje. Studie je založena na předpokladu existence vzájemného vztahu mezi hlavními faktory ekonomického růstu, a to inovační a ekonomickou výkonností. Příspěvek se nejprve zaměřuje na teoretické poznatky ze zkoumané oblasti a vymezuje faktory vstupující do analytické části. Závěrečná část příspěvku popisuje a diskutuje dosažené výsledky a nastiňuje další možné návaznosti budoucího výzkumu.

Klíčová slova:
Inovace, inovační výkonnost, patent, hrubý domácí produkt

JEL Classification: O11, A12, O34

1 Introduction

In the period of turbulence and global impacts on economies it is more and more obvious that economic growth is based on innovation, which significantly influences entrepreneurship in countries. Innovation cannot be ignored in all countries in the world. The term innovation has various definitions and can be understood in relation to different parts of industry, marketing, services or administration. It depends on an author´s perception of change as to what is considered innovation. According to Valenta, innovation can describe any change in an industrial organism (Valenta, 2001). Schumpeter (1934) defines innovation as an activity that creates economic growth. Romer (1990) maintains that technological change is a key factor of the income and economic growth of countries. For the purpose of this study, innovation is defined as any change which it is launched to commercial realisation into market and brings revenues and profit. This output of the innovation process is connected to the difficulty of its implementation in the production of a company and to the value of finished goods and services contributing to the gross domestic product of a country. It is necessary to protect technical invention by patent which is defined by the European Patent Office as a legal title that gives inventors the right, for a limited period, to prevent others from making, using or selling their invention without their permission in the countries for which the patent has been granted (European Patent Office, 2012). This definition is relevant to granted patents, but we consider a patent application as the result of innovation activities and human creativity, which should lead to entrepreneurship and the economic growth of the country from the macroeconomic point of view.

This paper focuses on the patent activities of leading European Union economies and analyses trends over the period of 10 years. The main aim of the article is to analyse trends in the patent applications of the most economically powerful countries of the European Union and to search for dependency between two indicators of economic growth: gross domestic product and innovation represented by the number of applications for patents to the European Patent office.

The paper is structured as follows. Section 2 offers the theoretical background and a literature review. Section 3 explains the methodology and data sources used. The main results are presented in Section 4, and discussed in Section 5, which also highlights the main conclusions of the study and explains the limitations of the analysis.

2 Innovation as an engine of economic growth

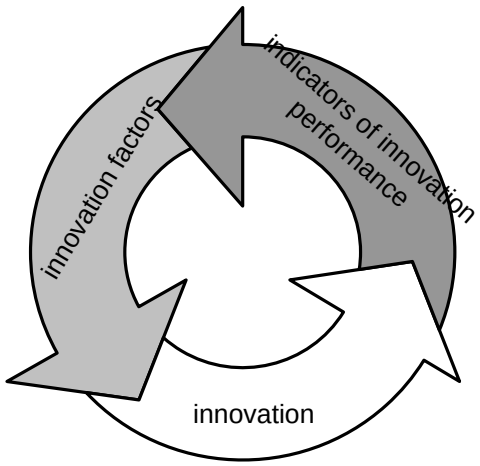
There is no doubt that economic growth is based on technological innovations, processes and services which are influenced by various factors. These factors enter directly, and indirectly, the innovation process and have an effect on the final output, which is measured by particular indicators. This paper first reviews the literature on the link between innovation activities and economic growth which is determined by many factors. Galindo and Méndez (2014) analyse relations between the innovations and economic growth of countries and their entrepreneurship. The authors examine factors that stimulate elements of the economy and confirmed the feedback effect between innovation and GDP. Trivedi's (2014) study is based on the assumption that three factors play a main role in economic growth, namely, technological inventions, process innovations and business practises, which directly influence innovation activities. The influence of innovation on economic growth is described in the paper of Popa and Vlasceanu (2014), who highlight the importance of innovation and its role in entrepreneurship. The study is based on the number of patents recorded by patent offices in selected countries; namely, China, the United States of America, Japan and Germany. These countries are stable leaders in innovation activities measured by patent applications and the study compared this factor with the economic indicator representing the GDP of given countries. Adak (2015) used Engel Granger and Error Correction Models for testing of a relation between economic growth and innovation in Turkey. Şener and Saridoğan (2011) analysed and investigated innovation and its effect on economic growth on macroeconomic level. They state innovation as a motor of economic growth, competitiveness and world development. Hasan and Tucci (2010) examined data of 58 countries and investigated how innovation transforms into economic development.

The study worked with economic growth presented by gross domestic product and patent applications. It was used a statistical research which confirmed that countries with higher level of patent activities tend to be countries with higher level of economic growth. A relation between patent activities and economic growth was analysed by Kim, Park and Choo (2011) who investigated patents and utility models and level of economic development. Lešková and Sabadka (2014) consider knowledge and its role in innovation, while Iwaisako and Futagami (2013) investigate how patent protection affects economic growth. These authors view innovation and capital accumulation as driving economic growth. Patent rights intensity and its impact on total productivity are examined by Hu and Pngy (2013), and Correa and Ornaghi (2014) search for evidence of competition and innovation. They use patent activities and productivity data from the USA for empirical analysis of the relationship of these two indicators. The primary factor of the study is chosen a number of granted patents related to other factors of innovation (new ideas, technological change, new technologies and better managerial practices). The results confirm the existence of a positive relationship between competition and innovation.

Based on the studies of other authors, it is expected that more factors influence the innovation process. These influences can be positive, leading to synergic or negative effect. If we understand patents as the results of innovative activities, which are measurable and comparable, we can assume a mutual relationship between three parts of the innovation cycle as shown in Figure 1. The main indicators and factors that are directly influencing innovation and the innovation process can cover:

- human capital,
- technological changes,
- R&D investments,
- education system,
- conditions for new inventions, etc.

Figure 1: The innovation cycle



Source: own work

This study is based on the assumption that the leading economies of the European Union have achieved their leadership in GDP not only on the basis of innovative activities. These activities are influenced by many factors that have mostly synergy effects and work on process and final product level

(launch into market). The premise is that more factors enter the innovation process and are necessary for successful innovation performance.

This study is part of research we are conducting and the presented results in our analysis can be influenced by further factors.

3 Used methodology and data sources

The methodology of the paper is in accordance with the paper´s main goal and the adoption of descriptive statistics. The dataset for this study comes from the Eurostat database and the descriptive characteristics of dynamics in calculations were used, namely, sequence of average absolute increases and mean growth coefficient.

Average absolute increase sequence is explained by difference in values sequence (also called sequence of first differences). The arithmetic mean from this data is calculated:

$$\Delta_t = y_t - y_{t-1} \qquad t = 2, 3, \ldots, n.$$

$$\bar{\Delta} = \frac{\sum \Delta_t}{n-1} = \frac{y_n - y_1}{n-1}.$$

Average growth coefficient is based on the growth coefficient of researched time series using geometric mean for calculation:

$$\bar{k} = \sqrt[n-1]{\frac{y_n}{y_1}}.$$

Estimation of trend function parameters is utilised to examine variables dependence.

3.1 Indicator of economic performance

The present study used data extracted from the Eurostat database which includes measurable indicators of European Union members. The primary factor for country selection was an indicator of economic performance, meaning gross domestic product (GDP) calculated in market prices. This indicator was selected due to the complexity of the problem itself and for its relevance to solution searching as regards the issue of economic growth and innovative activities in the European Union area.

As it has been mentioned, data were extracted from the Eurostat database only and collected for the period 2003–2012. It represents time data series before and after global crisis and affected by turbulences in all fields of economies from various periods of time. The countries with the highest GDP were ranked (basic dataset is the GDP of 28 EU members) and then we focused on the top three economies (based on rank in 2012) for further analysis. This indicator was used in two parameters: in absolute values and compared with inhabitants of particular countries. The rank of all EU economies is displayed in Table 1.

Table 1: Gross domestic product in the European Union countries, based on rank in 2012 (in million Euros)

country/time	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	total 2012 (cumulatively)
Germany	2 147 500,0	2 195 700,0	2 224 400,0	2 313 900,0	2 428 500,0	2 473 800,0	2 374 200,0	2 495 000,0	2 609 900,0	2 666 400,0	20,6%
France	1 587 901,8	1 655 571,8	1 718 047,0	1 798 115,3	1 886 792,1	1 933 195,0	1 885 761,9	1 936 719,7	2 001 398,0	2 032 296,8	36,3%
United Kingdom	1 659 740,7	1 787 298,5	1 867 129,3	1 979 497,7	2 086 519,9	1 836 125,5	1 590 858,0	1 731 809,0	1 770 909,6	1 921 904,9	51,1%
Italy	1 341 850,1	1 397 728,3	1 436 379,5	1 493 031,3	1 554 198,9	1 575 143,9	1 519 695,1	1 551 885,6	1 579 946,4	1 566 911,6	63,2%
Spain	783 082,0	841 294,0	909 298,0	985 547,0	1 053 161,0	1 087 788,0	1 046 894,0	1 045 620,0	1 046 327,0	1 029 002,0	71,1%
Netherlands	476 945,0	491 184,0	513 407,0	540 216,0	571 773,0	594 481,0	573 235,0	586 789,0	599 047,0	599 338,0	75,7%
Sweden	278 914,0	291 634,1	298 353,3	318 170,8	337 944,2	333 255,7	292 472,1	349 945,1	385 450,7	407 820,3	78,9%
Poland	191 643,8	204 236,5	244 420,1	272 088,9	311 001,7	363 175,3	310 681,4	354 616,1	370 850,6	381 479,7	81,8%
Belgium	276 157,0	291 287,0	303 435,0	318 829,0	335 815,0	346 375,0	340 669,0	355 791,0	369 258,0	375 852,0	84,7%
Austria	224 996,0	234 707,8	245 243,4	259 034,5	274 019,8	282 744,2	276 228,0	285 165,3	299 240,4	307 003,8	87,1%
Denmark	188 500,3	197 069,9	207 366,9	218 747,4	227 533,9	235 133,0	223 575,8	236 334,1	240 487,1	245 252,0	89,0%
Greece	172 431,1	185 265,6	193 049,7	208 621,8	223 160,1	233 197,7	231 081,2	222 151,5	208 531,7	193 347,0	90,5%
Finland	145 531,0	152 266,0	157 429,0	165 765,0	179 830,0	185 670,0	172 318,0	178 724,0	188 744,0	192 350,0	92,0%
Portugal	143 471,7	149 312,5	154 268,7	160 855,4	169 319,2	171 983,1	168 529,2	172 859,5	171 126,2	165 107,4	93,2%
Ireland	140 635,1	150 024,5	162 896,8	177 573,5	189 654,7	180 249,5	162 283,5	158 096,7	162 599,7	163 938,7	94,5%
Czech Republic	84 409,6	91 849,5	104 628,8	118 290,8	131 908,6	154 269,7	142 197,0	149 932,0	155 486,0	152 925,6	95,7%
Romania	52 576,5	61 063,9	79 801,9	97 751,0	124 728,5	139 765,4	118 196,0	124 327,7	131 478,0	131 578,9	96,7%
Hungary	73 883,0	82 114,8	88 765,5	89 589,9	99 422,8	105 535,8	91 415,4	96 243,0	98 920,6	96 968,3	97,5%
Slovakia	29 489,2	33 994,6	38 489,1	44 501,7	54 810,8	64 413,5	62 794,4	65 897,0	68 974,2	71 096,0	98,0%
Croatia	30 246,7	33 004,9	36 030,1	39 734,6	43 380,4	47 538,3	44 778,3	44 423,4	44 191,0	43 477,0	98,3%
Luxembourg	25 822,1	27 444,5	30 269,5	33 914,1	37 496,8	37 371,5	35 575,2	39 302,6	41 729,7	42 917,8	98,7%
Bulgaria	18 374,4	20 387,9	23 255,8	26 476,7	30 772,4	35 430,5	34 932,8	36 052,4	38 504,9	39 927,0	99,0%
Slovenia	25 819,2	27 227,5	28 730,9	31 050,7	34 593,6	37 244,4	35 420,2	35 484,6	36 150,0	35 318,6	99,2%
Lithuania	16 576,1	18 244,8	20 969,1	24 104,2	28 738,8	32 414,3	26 654,4	27 709,7	30 958,5	32 939,8	99,5%
Latvia	9 942,5	11 154,6	12 927,8	15 981,9	21 026,5	22 889,8	18 521,3	18 038,9	20 211,3	22 257,0	99,7%
Cyprus	11 654,2	12 596,0	13 598,2	14 670,5	15 901,5	17 157,1	16 853,5	17 406,0	17 878,0	17 720,2	99,8%
Estonia	8 724,0	9 692,2	11 189,1	13 396,2	16 071,3	16 239,5	13 973,4	14 530,4	16 197,5	17 460,1	99,9%
Malta	4 639,9	4 669,9	4 930,9	5 206,7	5 575,4	5 963,5	5 956,0	6 458,5	6 691,9	6 913,2	100,0%
European Union	10 151 451,9	10 658 018,6	11 128 703,0	11 764 657,3	12 473 648,9	12 548 545,7	11 815 746,6	12 337 153,6	12 711 206,8	12 959 735,7	100,0%

Data source: Eurostat, own calculations

We can see in Table 1 that Germany is the leading country in economic performance with GDP over 2 666 400 mil. Euros in 2012. France is in second place, with more than 2 trillion Euros, and in third place, reaching almost 2 trillion Euros in performance, is the United Kingdom. These three economies generate more than 50% of EU countries' economic performance, according to the statistics. This is the key fact; we consider these countries as economic leaders and focus on their innovation activities in further analysis.

Tab 2: Gross domestic product of EU countries, based on rank 2012 (in Euro per inhabitants)

country/time	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Luxembourg	57 100	59 900	65 000	71 700	78 000	76 400	71 400	77 400	80 300	80 700
Denmark	35 000	36 500	38 300	40 200	41 700	42 800	40 500	42 600	43 200	43 900
Sweden	31 100	32 400	33 000	35 000	36 900	36 100	31 500	37 300	40 800	42 800
Austria	27 700	28 700	29 800	31 300	33 000	34 000	33 100	34 100	35 700	36 400
Netherlands	29 400	30 200	31 500	33 100	34 900	36 200	34 700	35 300	35 900	35 800
Ireland	35 200	36 900	39 200	41 600	43 100	40 100	35 800	34 700	35 500	35 700
Finland	27 900	29 100	30 000	31 500	34 000	34 900	32 300	33 300	35 000	35 500
Belgium	26 600	28 000	29 000	30 200	31 600	32 400	31 600	32 700	33 600	34 000
Germany	26 000	26 600	27 000	28 100	29 500	30 100	29 000	30 500	31 900	32 600
France	25 600	26 500	27 300	28 400	29 600	30 100	29 300	29 900	30 700	31 100
United Kingdom	27 900	29 900	31 000	32 700	34 200	29 900	25 700	27 800	28 200	30 200
Italy	23 300	24 000	24 500	25 300	26 200	26 300	25 200	25 700	26 000	25 700
Spain	18 600	19 700	21 000	22 400	23 500	23 900	22 800	22 700	22 700	22 300
Cyprus	16 200	17 300	18 400	19 500	20 700	21 800	20 900	21 000	21 000	20 500
Greece	15 600	16 800	17 400	18 700	20 000	20 800	20 700	19 900	18 700	17 400
Slovenia	12 900	13 600	14 400	15 500	17 100	18 400	17 300	17 300	17 600	17 200
Malta	11 600	11 600	12 200	12 800	13 700	14 600	14 400	15 600	16 100	16 500
Portugal	13 700	14 200	14 600	15 200	16 000	16 200	15 900	16 300	16 100	15 600
Czech Republic	8 300	9 000	10 200	11 500	12 800	14 800	13 600	14 300	14 800	14 600
Slovakia	5 500	6 300	7 100	8 300	10 200	11 900	11 600	12 100	12 800	13 200
Estonia	6 400	7 200	8 300	10 000	12 000	12 100	10 400	10 800	12 100	13 000
Lithuania	4 900	5 400	6 300	7 400	8 900	10 100	8 400	8 900	10 200	11 000
Latvia	4 300	4 900	5 800	7 200	9 600	10 500	8 600	8 600	9 800	10 900
Croatia	7 000	7 700	8 400	9 200	10 100	11 000	10 400	10 300	10 300	10 200
Poland	5 000	5 300	6 400	7 100	8 200	9 500	8 100	9 200	9 600	9 900
Hungary	7 300	8 100	8 800	8 900	9 900	10 500	9 100	9 600	9 900	9 800
Romania	2 400	2 800	3 700	4 600	6 000	6 800	5 800	6 100	6 500	6 600
Bulgaria	2 400	2 600	3 000	3 400	4 000	4 600	4 600	4 800	5 200	5 500
European Union	20 600	21 600	22 400	23 600	25 000	25 000	23 500	24 400	25 100	25 500

Data source: Eurostat

For verification, we extracted further data that should confirm their position as leading economies of the European Union. As mentioned above, GDP is influenced – like innovation - by many factors. One of these factors, we used in our analysis, is human capital. Therefore, we focused on GDP compared with the population (inhabitants) of EU member (28) countries.

Table 2 shows a ranking of the GDP compared with number of inhabitants of particular countries. Luxembourg is the state with the highest economic performance, Denmark is placed second and Sweden completes the ranking of the three best countries. If we compare this indicator with the ranking of countries with amounts calculated in total values, the displayed countries obtained the best results in both classifications, as shown in Table 3. This classification includes all countries of the EU that generate 90 % of European Union economic performance.

Table 3: Gross domestic product and ranks of the selected countries

country/rank	GDP in total values	GDP per inhabitant
Germany	1.	9.
Austria	10.	4.
Belgium	9.	8.
Denmark	11.	2.
France	2.	10.
Greece	12.	15.
Italy	4.	12.
Netherlands	6.	5.
Poland	8.	25.
Spain	5.	13.
Sweden	7.	3.
United Kingdom	3.	11.

Source: own calculations

The results shown in the tables above indicate countries with high economic performance and compared with number of inhabitants. In most published statistics, gross domestic product is used as a basic indicator for comparing economies and their performance. Data are presented in Table 1. In accordance with data found in the statistics of relevant sources (Eurostat, OECD, World Bank, etc.), we decided to examine the rank of GDP summarised in absolute values as is usually the case.

Working on the assumption of this paper, it can be expected similar order for the EU countries, primarily on leading positions, in the rank of patent applications. These factors are interconnected and we state, based on the theoretical part of this paper, that the more productive economy generates applicable innovation and reaches better results in research and development.

3.2 Patent applications

The second parameter of analysis in this study is innovation performance measured by number of patent applications registered by the European Patent Office. According to this study, the number of applications for patents represents the innovative activities of countries. Explanation and comparison of innovation performance is very difficult because of data collection and data relevance for further analysis.

For the purpose of this paper, we calculate using number of patent applications, which are usually defined as requests for patent. Patent application as a concept of our study means the final result of human capital and other factors entering the innovation process and represents the creativity and originality of a solved problem. Patents are considered the highest level of industrial property rights, which is very difficult to reach (Eurostat, 2014). The technical solution has to be regarded as sophisticated and innovative for patenting and there has to exist a need for protection on this high level of industrial rights. The invention has to be new and applicable in industry. Not all of the patent applications are finally granted due to the complexity and evaluation of solution originality. The number of granted patents is lower than applications recorded in the patent office; this fact is not reflected in the study. Our study considers human creativity and thinking leading to innovative results measured by number of patent applications.

We can state that European countries primarily apply their patents to EPO in accordance with European Patent System. Patent applications are assigned with residency of first named applicant. The residency is the primary factor for statistics of particular countries. Obviously, request for patent is also applied in other foreign offices. The real number of patent applications of selected countries is higher worldwide than we present in our study.

The present study, as previously mentioned, is only part of a huge research project. Due to this fact, patent applications in the European Patent Office, not worldwide, are considered. The dataset has been extracted from the Eurostat and includes all EU members, the 28 countries of the European Union. The countries were ranked with regard to number of applications for patents summarised in total values.

Analysed data are collected for the period 2003-2012. The rank is based on number of patent applications to EPO, compiled from results in 2012. It is calculated that the three most innovative countries account for more than two-thirds of European patents (64,7 %). The total number of applications in the whole European Union was about 57,000 in 2012 (57 423,3).

Table 4: Patent applications of the European Union countries in the period 2003–2012 (total numbers)

country/time	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	total 2012 (cumulatively)
Germany	22 203,4	23 118,6	24 034,7	24 092,0	24 339,3	23 069,4	23 338,9	23 262,7	22 903,8	22 848,7	39,8%
France	7 956,6	8 339,1	8 384,2	8 498,5	8 635,2	8 710,6	8 631,9	8 444,4	8 871,8	8 925,5	55,3%
United Kingdom	5 664,3	5 611,7	5 651,0	5 782,0	5 584,5	5 325,1	5 374,9	5 264,0	5 344,4	5 350,8	64,7%
Italy	4 394,7	4 590,6	4 907,2	5 063,4	4 911,4	4 738,5	4 402,8	4 469,7	4 372,4	4 250,4	72,1%
Netherlands	3 498,4	3 662,7	3 507,1	3 727,8	3 327,7	3 438,7	3 419,6	3 033,3	3 416,0	3 408,5	78,0%
Sweden	2 055,7	2 243,3	2 436,0	2 629,3	2 820,5	2 763,3	2 596,8	2 777,1	2 799,4	2 811,5	82,9%
Austria	1 389,9	1 446,8	1 523,3	1 745,8	1 716,7	1 621,8	1 696,3	1 749,1	1 785,3	1 839,8	86,1%
Spain	962,6	1 214,1	1 360,4	1 348,8	1 386,0	1 429,8	1 527,8	1 496,8	1 533,7	1 568,4	88,8%
Belgium	1 362,7	1 516,4	1 512,6	1 538,5	1 562,8	1 489,9	1 400,9	1 501,7	1 501,7	1 505,7	91,4%
Denmark	1 110,8	1 110,0	1 190,0	1 138,6	1 297,0	1 293,0	1 189,4	1 268,8	1 451,6	1 504,4	94,1%
Finland	1 293,5	1 405,2	1 335,5	1 346,2	1 271,2	1 258,5	1 310,2	1 377,7	1 413,2	1 464,8	96,6%
Poland	109,3	124,4	127,9	139,3	202,0	232,0	286,0	359,3	411,7	471,7	97,4%
Ireland	226,6	272,5	275,3	292,9	327,1	327,0	341,2	313,2	367,7	381,3	98,1%
Hungary	133,1	153,4	135,6	164,1	191,1	180,2	184,2	193,1	217,6	230,0	98,5%
Czech Republic	110,9	112,2	107,6	152,3	188,6	207,6	174,8	191,6	219,8	223,8	98,9%
Portugal	66,7	58,7	122,9	106,5	122,8	114,1	92,2	94,6	116,0	116,7	99,1%
Slovenia	73,4	111,9	108,4	99,4	119,1	138,9	123,3	103,9	110,1	100,5	99,3%
Greece	85,0	65,3	110,6	106,1	103,8	93,9	93,1	65,3	84,3	81,0	99,4%
Luxembourg	87,2	114,9	98,4	107,0	73,5	92,9	74,9	76,3	77,3	72,0	99,5%
Romania	16,3	23,2	28,7	20,2	32,6	32,5	31,1	34,4	58,4	67,0	99,7%
Slovakia	31,4	20,6	31,3	40,4	38,6	36,9	28,9	46,5	53,6	59,2	99,8%
Estonia	10,4	8,5	6,4	21,2	28,2	35,3	44,0	37,4	40,5	42,2	99,8%
Croatia	40,5	32,1	33,4	35,5	30,2	28,9	22,0	29,3	29,0	29,1	99,9%
Bulgaria	21,3	17,6	23,3	27,1	12,2	18,7	15,8	17,0	26,4	29,0	99,9%
Lithuania	16,9	11,1	8,8	9,7	9,8	16,9	8,3	15,9	17,9	18,3	100,0%
Latvia	7,1	9,8	17,8	16,4	15,7	22,8	18,7	15,8	17,9	16,3	100,0%
Cyprus	5,0	6,0	16,8	6,3	10,3	11,3	15,2	7,7	6,8	5,3	100,0%
Malta	3,3	6,0	11,3	7,9	6,5	5,5	7,8	3,5	2,5	1,5	100,0%
European Union	52 936,8	55 406,6	57 106,5	58 263,1	58 364,2	56 733,7	56 451,3	56 250,1	57 250,9	57 423,3	100,0%

Data source: Eurostat, own calculations

Table 4 shows that Germany is the leading country in innovation activities with more than 22 thousands patents. France is in second position (8 925,5), followed by the United Kingdom with 5 350,8 patents.

Table 5: Patent applications of EU countries, based on rank 2012 (per million inhabitants)

country/time	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sweden	229,9	249,9	270,3	290,6	309,5	300,9	280,5	297,3	297,3	296,5
Germany	269,0	280,1	291,3	292,2	295,7	280,6	284,6	284,4	280,2	279,2
Finland	248,5	269,2	255,0	256,1	240,9	237,4	246,0	257,5	262,9	271,2
Denmark	206,3	205,7	219,9	209,8	238,1	236,1	215,8	229,2	261,1	269,6
Austria	171,6	177,7	185,7	211,5	207,3	195,2	203,5	209,4	213,2	218,8
Netherlands	216,1	225,3	215,1	228,2	203,4	209,6	207,4	183,0	205,1	203,7
Luxembourg	194,5	252,5	213,4	228,2	154,3	192,0	151,8	152,0	150,9	137,2
France	128,6	133,9	133,6	134,4	135,7	136,1	134,1	130,6	136,5	136,7
Belgium	131,6	145,9	144,8	146,4	147,7	139,7	130,3	138,5	136,5	135,7
United Kingdom	95,2	93,9	93,9	95,4	91,4	86,5	86,6	84,2	84,8	84,3
Ireland	57,2	67,6	67,0	69,6	75,4	73,4	75,5	68,8	80,4	83,2
Italy	76,9	79,8	84,8	87,2	84,4	80,8	74,6	75,5	73,7	71,6
Slovenia	36,8	56,0	54,3	49,6	59,3	69,1	60,6	50,8	53,7	48,9
Spain	23,0	28,5	31,4	30,7	31,0	31,3	33,0	32,2	32,9	33,5
Estonia	7,6	6,2	4,7	15,7	21,0	26,4	32,9	28,1	30,5	31,9
Hungary	13,1	15,2	13,4	16,3	19,0	17,9	18,4	19,3	21,8	23,2
Czech Republic	10,9	11,0	10,6	14,9	18,4	20,1	16,8	18,3	21,0	21,3
Poland	2,9	3,3	3,4	3,7	5,3	6,1	7,5	9,4	10,7	12,2
Portugal	6,4	5,6	11,7	10,1	11,7	10,8	8,7	9,0	11,0	11,1
Slovakia	5,8	3,8	5,8	7,5	7,2	6,9	5,4	8,6	10,0	11,0
Latvia	3,1	4,3	7,9	7,4	7,1	10,4	8,6	7,4	8,6	8,0
Greece	7,7	5,9	10,0	9,6	9,3	8,4	8,3	5,8	7,6	7,3
Croatia	9,4	7,5	7,7	8,2	7,0	6,7	5,1	6,8	6,8	6,8
Cyprus	7,1	8,3	22,9	8,5	13,6	14,5	19,1	9,4	8,1	6,1
Lithuania	4,9	3,3	2,6	2,9	3,0	5,3	2,6	5,1	5,9	6,1
Bulgaria	2,7	2,3	3,0	3,5	1,6	2,5	2,1	2,3	3,6	4,0
Malta	8,2	15,0	27,9	19,4	16,0	13,5	19,0	8,5	6,0	3,6
Romania	0,8	1,1	1,3	1,0	1,5	1,6	1,5	1,7	2,9	3,3
European Union	107,85	112,45	115,42	117,32	117,1	113,37	112,41	111,74	112,73	112,6

Data source: Eurostat

The highest increase in innovation performance, compared with number of inhabitants of country, was in Sweden (296,8). Germany, as a leading country in previous indicators, generated 279,2 requests for patents and Finland is the third most successful country with 271,2 applications, as shown in Table 5.

We then compare all previous results based on the rank of the countries (all countries that generate more than 90 % of economic performance of the European Union), and present the summary of results in Table 6.

Table 6: Results summary of selected indicators of European Union members

country/rank	GDP in total values	GDP per inhabitant	Patent applications in total numbers	Patent applications per million inhabitants
Austria	10.	4.	7.	5.
Belgium	9.	8.	9.	9.
Denmark	11.	2.	10.	4.
France	2.	10.	2.	8.
Germany	1.	9.	1.	2.
Greece	12.	15.	18.	22.
Italy	4.	12.	4.	12.
Netherlands	6.	5.	5.	6.
Poland	8.	25.	12.	18.
Spain	5.	13.	8.	14.
Sweden	7.	3.	6.	1.
United Kingdom	3.	11.	3.	10.

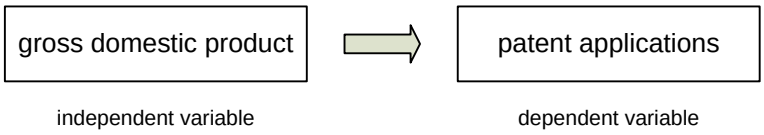
Source: own calculations

The summary of results indicates the choice of countries that will be analysed in detail. Table 6 shows the positions of the countries in terms of the different indicators. Germany is a leading country in GDP calculated for the whole economy and number of applied patents to EPO in 2012. France is in second place in GDP indicator and also in requests for patents in absolute values. The third most successful country in two monitored categories is the United Kingdom. These three countries are analysed in further detail below.

3.3 Variables of the study

Due to the innovation cycle, the premise of study is factors interdependence. We focus on economic performance and search for dependence on innovation. The number of patent applications to the European Patent Office is a dependent variable used in this study. For the independent variable gross domestic product is chosen. We analyse the dependency of patent applications on the economic performance of selected countries and compare achieved results within these countries, as shown in Figure 2.

Figure 2: Variables used in the study



Source: own work

4 Results

This part of the study presents the results of analysis in detail. It is analysed the trend in patent application development first due to its determination of dependent variable. After these calculations, we analyse a dependency of innovation activities on the economic performance of selected countries below and determine the degree of their dependence. The three most economically powerful countries have been analysed, namely, Germany, France and the United Kingdom.

4.1 Germany and its patent applications trend

Table 7 presents the final calculations for Germany. In 2008, there was a decrease in patent applications and this trend continued in the period 2010–2012. The highest number of patent applications was (24 296) in 2007.

Table 7: Germany and patent applications trend calculations

Germany				
year	y_i	t	$\Delta_t = y_t - y_{t-1}$	$k_t = \frac{y_t}{y_{t-1}}$
2003	22 193,4	1	.	.
2004	23 103,6	2	910,2	1,041
2005	24 010,9	3	907,3	1,039
2006	24 073,3	4	62,3	1,003
2007	24 296,4	5	223,1	1,009
2008	23 038,1	6	-1 258,4	0,948
2009	23 272,9	7	234,8	1,010
2010	23 199,7	8	-73,2	0,997
2011	22 834,2	9	-365,6	0,984
2012	22 766,2	10	-68,0	0,997

Source: own work

The trend shows that the number of requested patents dropped in absolute changes. The highest number of patent applications was registered in a period before the economic crisis, and it decreased to its lowest level in 2012. This trend is still decreasing and it has not reached the number of applications before the crisis. However, if the economies of EU countries are in a better condition, we can expect an increasing trend in patent applications in accordance with economic development.

Average absolute increase is calculated as 63,6 patents per year:

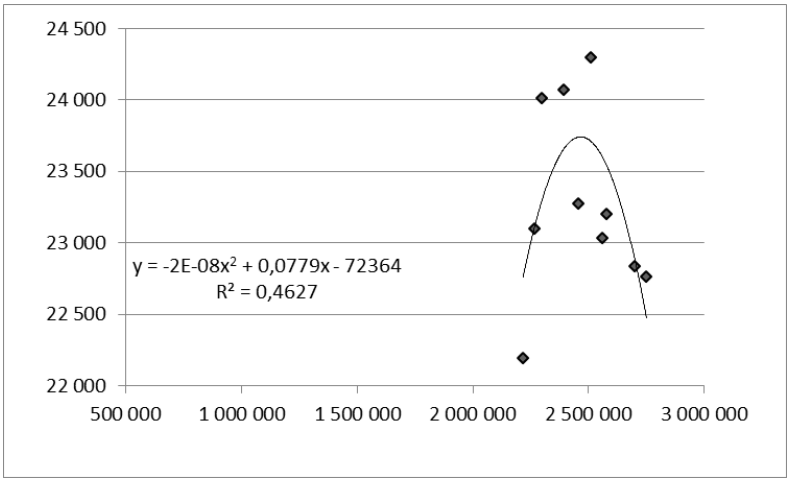
$$\bar{\Delta} = \frac{y_n - y_1}{n - 1} = \frac{22\,766{,}2 - 22\,193{,}4}{10 - 1} = 63{,}6$$

If we consider growth coefficient, it is calculated as the value of 1,003 for the period of 10 years:

$$\bar{k} = \sqrt[9]{1{,}041 \cdot 1{,}039 \cdot 1{,}003 \cdot 1{,}009 \cdot 0{,}948 \cdot 1{,}010 \cdot 0{,}997 \cdot 0{,}984 \cdot 0{,}997} = 1{,}003$$

Polynomial trend line is chosen for prediction of future development of this indicator and for determining gross domestic product and patent applications. This chosen trend line is a form of linear regression used when data fluctuate. The order of the polynomial can be determined by the number of fluctuations in data and fits a nonlinear relationship. The final data for trend and trend line for Germany are graphically displayed in Figure 3.

Figure 3: Polynomial trend line in German patent applications



Source: own work

We can predict with 46% probability that Germany's number of patent applications will copy the polynomial curve based on independent variable, in the case of our study the indicator of gross domestic product. This value of probability can be considered as on a high level because of existence of many further factors influencing innovation performance and entering this process. We analyse the only entering factor. From this point of view, this dependency is very close.

4.2 France and its patent applications trend

We see, in Table 8, that patent applications have decreased in France since 2009, which is comparable with Germany's analysed data. There were 8 694,8 patent applications in 2008 and the trend fell to 8 251,8 patents in 2012. The results of this monitored indicator have not reached the values that were recorded before the economic crisis.

Table 8: France and patent applications trend calculations

France				
year	y_i	t	$\Delta_t = y_t - y_{t-1}$	$k_t = \frac{y_t}{y_{t-1}}$
2003	7 951,3	1	.	.
2004	8 333,8	2	382,5	1,048
2005	8 379,7	3	45,9	1,006
2006	8 482,7	4	103,0	1,012
2007	8 631,2	5	148,5	1,018
2008	8 694,8	6	63,6	1,007
2009	8 617,1	7	-77,7	0,991
2010	8 429,7	8	-187,4	0,978
2011	8 362,6	9	-67,2	0,992
2012	8 251,8	10	-110,8	0,987

Source: own work

Absolute change in patent applications made by French residents to the EPO is calculated as 33,38 patents on average for the period 2003–2012. This is a lower number than in the case of Germany. We see Germany´s performance as more powerful.

The trend in number of requested patents has been decreasing since 2008 and average absolute change still reaches negative numbers.

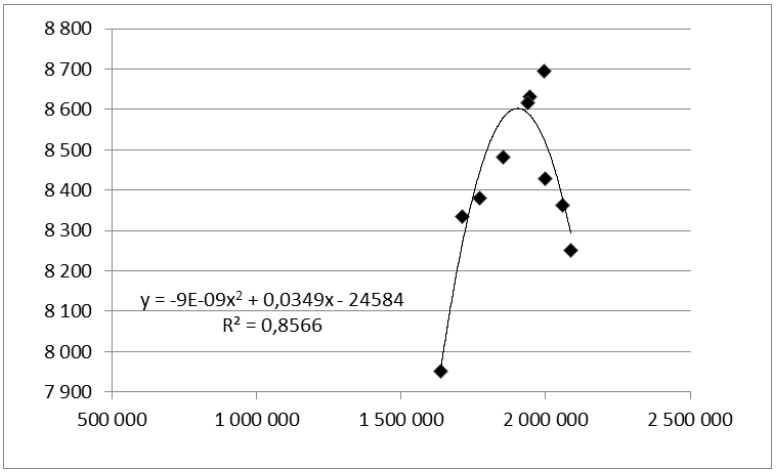
$$\bar{\Delta} = \frac{y_n - y_1}{n-1} = \frac{8\,251{,}8 - 7\,951{,}3}{10-1} = 33{,}38$$

In terms of growth coefficient, this is calculated as the value of 1,004 patents in the period of 10 years:

$$\bar{k} = \sqrt[9]{1{,}041 \cdot 1{,}039 \cdot 1{,}003 \cdot 1{,}009 \cdot 0{,}948 \cdot 1{,}010 \cdot 0{,}997 \cdot 0{,}984 \cdot 0{,}997} = 1{,}003$$

As we see in Figure 4, polynomial trend line is defined by equation with more than 85 % of probability. This value is very high and the dependency of these two indicators is very close. With ascertained value of GDP per year, we can expect development in patent applications which is not as influenced by further effects as in the case of Germany. GDP has a direct impact on number of patent applications and probably indicates the number of requests for patents in accordance with economic development. Trend, explained by polynomial function, is graphically displayed in Figure 4.

Figure 4: Polynomial trend line in French patent applications



Source: own work

4.3 The United Kingdom and its patent applications trend

The results for the United Kingdom show that patent applications have decreased since 2006 (see Table 9). There were 5 767,0 patent applications and the trend in development fell to 5 062,6 patents in 2012. The results of this indicator have not reached values recorded before 2006. The number of patent applications was decreasing and this trend has not stopped. Due to this fact, we can expect a decrease in further years.

Table 9: The United Kingdom and patent applications trend calculations

United Kingdom				
year	y_i	t	$\Delta_t = y_t - y_{t-1}$	$k_t = \frac{y_t}{y_{t-1}}$
2003	5 656,0	1	.	.
2004	5 591,3	2	-64,7	0,989
2005	5 627,7	3	36,4	1,007
2006	5 767,0	4	139,3	1,025
2007	5 565,9	5	-201,1	0,965
2008	5 311,0	6	-254,9	0,954
2009	5 353,7	7	42,7	1,008
2010	5 235,0	8	-118,7	0,978
2011	5 124,7	9	-110,3	0,979
2012	5 062,6	10	-62,1	0,988

Source: own work

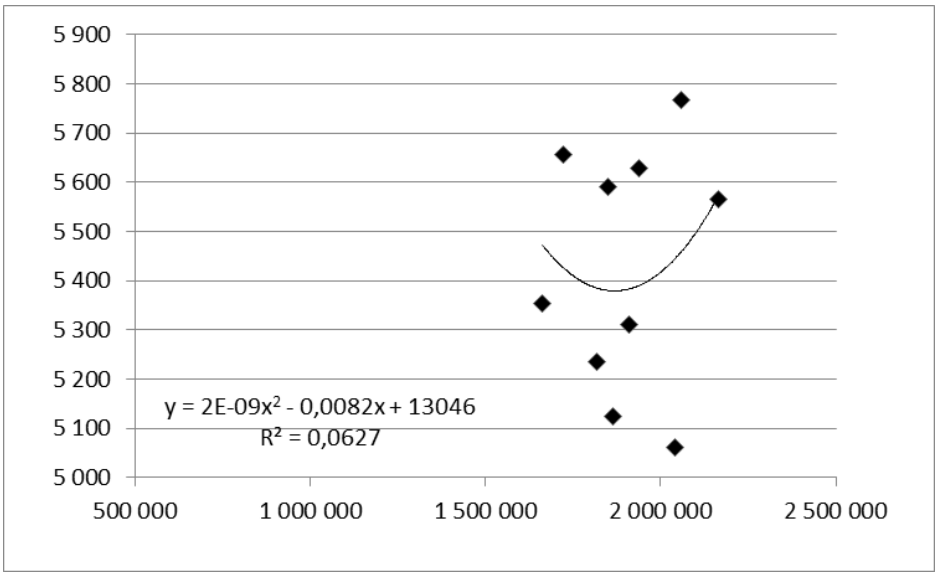
The results calculated in Table 9 indicate very huge dispersion in values and the problem of accurate prediction. As it is confirmed by polynomial trend, dependency between these two indicators does not exist and the number of patent applications in the UK is influenced by other factors mostly, not by GDP directly (see Figure 5). The average of absolute change is calculated in negative values.

In terms of growth coefficient, this is calculated as the value of 0,988 in the period of 10 years:

$$\bar{\Delta} = \frac{y_n - y_1}{n-1} = \frac{5\,062{,}6 - 5\,656{,}0}{10-1} = -65{,}93$$

$$\bar{k} = \sqrt[9]{0{,}989 \cdot 1{,}007 \cdot 1{,}025 \cdot 0{,}965 \cdot 0{,}954 \cdot 1{,}008 \cdot 0{,}978 \cdot 0{,}979 \cdot 0{,}988} = 0{,}988$$

Figure 5: Polynomial trend line in British patent applications



Source: own work

As we see from the results, the performance of the UK is the weakest of the selected countries and reached diffuse values. The growth coefficient is calculated in negative values and it is very difficult to

predict future development. The dependency of GDP and patent applications does not exist. We cannot state that higher economic performance will lead to higher expenditures on research and development and therefore a higher number of patent applications with requirement to protect new inventions and innovation. This dependency has to be searched for in other factors entering innovation in the innovation cycle.

5 Discussion, limitations and conclusion of the study

The obtained results of the study show a polynomial trend in patent applications to gross domestic product. We can interpret such a trend as an effort to predict the future development of this important indicator of innovation performance in connection with the economic growth of selected countries.

The total number of EPO patent requests confirmed Germany as the most innovative country in the European Union with fluctuation of values caused probably by economic crises. The number of total patent applications leads to various results and changes over a period of time. If we compare the data reported by the European Patent Office with worldwide statistics, we can estimate problems in determination of innovation performance. As described in the theoretical part of the study, innovation is based on many factors which are very difficult to define. This was confirmed by the results of our analysis. The analysis showed large differences between monitored countries and a problem in the innovation policy of the EU. As we know from the Innovation Union Scoreboard 2015 (European Commission, 2015), the countries of the EU are divided into four categories: innovation leaders, innovation followers, moderate innovators and modest innovators with differences in innovation performance of particular countries. This Scoreboard is divided into 25 categories and determines a summary index for countries' ranking. Germany belongs into group of EU leaders, France and United Kingdom follow innovators. These countries belong to driving forces of the European Union, help to accelerate a development of new technologies and also their application into manufacturing and successful product and service innovation. This fact confirmed study of Biglu (2010) who compared and analysed results of patent activities of all countries applied to particular patent offices. He focused on the most innovative countries of the world (USA, Japan, Germany, United Kingdom, France and Canada) in detail. His results confirmed a relation between gross domestic product and innovation activities and shown more facts in this area of scientific research.

It is necessary to analyse more factors in detail and complexly and include other factors entering innovation such as investment in research and development, human capital represented by number of researchers, the role of technologies in the twenty first century, etc. This study has demonstrated the realities of patent applications trends and confirmed the position of Germany as one of leading countries of innovation performance in the European Union.

This study should be understood as part of a more complex research, whose main task is to answer the question of innovation and the factors influencing the innovation process. The framework of investigation was outlined and this research will cover more indicators of countries' performance.

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