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ECONOMETRIC ANALYSIS OF SELECTED FACTORS OF INNOVATIVE COMPANIES ACTIVITY IN THE POLISH ECONOMY

Abstract

Today, a particularly important role in the functioning and development of enterprises plays innovation. This is understood as the ability to create innovative space capable to the creation and diffusion of innovation. Nowadays, a thriving innovation activity is identified with the achievement of business success in the economic arena. With this in mind it is worth exploring the determinants of innovation. It is therefore this article was proposed. The study analyzed the impact of GDP, internal expenditure on R&D and capital expenditures on the size of innovative activities of enterprises located in the sixteen Polish provinces. The research was limited to a period of seven years, i.e. from 2008 to 2014. The aim of this article is therefore to determine the level of significance of some factors influencing the size of innovation activities in Polish enterprises. To achieve the objective the analysis of statistical data was carried out and the panel model calculated by the classical method of least squares was built. Conducted tests will verify three research hypotheses. The software GNU Regression Econometric and Time-Series Library - GRETL was used for calculations.

JEL Classification Codes: **C50, E22, O32.**

Keywords: Innovative activity, the companies, Poland, panel model, the classical method of least squares.

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Introduction

Currently, various types of events, for example, economical (more Krištofík, Lament, et al., 2015), social or natural are generally conditioned by the action of other phenomena. Thus, the presence of relationships between phenomena is most often the subject of scientific discussion, both theoretical and practical. Therefore, the presented article was dedicated to the examination of innovative activity of Polish companies in relation to the three selected factors. This group includes GDP, internal expenditure on R&D and capital expenditures. It is known that in the modern world the development of innovation is the result of the interaction of many different factors, therefore, it is extremely reasonable to examine the significance although some of them. So, the aim of this article is to determine the level of significance of some factors affecting the size of innovative activity managing by companies functioning in sixteen Polish provinces in 2008-2014. The studies did not include the last year, i.e. 2015 due to lack of data at the time of preparation of the proposed analysis.

1. Literature review

The literature concerning the studied matter is very rich and extensive. Therefore, in the presented considerations, the theoretical aspect was deliberately very limited and therefore encourages readers to deepen theoretical knowledge by studying widely available scientific publications (see Francik, Szczepańska-Woszczyna, Dado, 2016; Gorka 2014, Kloska 2015). While the main task of that article is to present the results of own research, and the following brief theoretical outline is only an introduction to the issue.

In the contemporary economy, no one questions the importance of innovation (Barbachowska, 2014), but it is more often emphasized that they are the foundation of the development of businesses and the main message of achieving a competitive advantage. On that point it is worth mentioning the genesis of innovation. Well, the concept of innovation comes from Latin - innovare and means to create something new. However, this concept was first introduced to the economic sciences in 1911 by J. Schumpeter. He believed that the essence of innovation is to use resources of the production in a new, not yet used method, while releasing them from current uses (Schumpeter, 1939). The following Table 1 presents summary of the various positions regarding the definition of innovation.

Table 1. A variety of approaches to define innovation

Author	The definition of innovation
P. F. Drucker	Specifies innovation from the perspective of changes. Changes form the basis for innovation as they cause that new products or services are created.
M. E. Porter	Innovations are considered as technological improvements, better methods or ways to do the things.
P. R. Whitfield	Innovation is a complex sequence of actions involving problem solving. The result is a novelty.
J. Peter	The difference between innovation and routine business activity is based on four pillars: novelty, complexity, risk and potential conflict.
OEWG	It involves the implementation of a new or significantly improved product (good or service), or process, a new marketing/organizational method in business practices.
Eurostat	Implementation of new or significantly improved (good or service), process, new marketing method or a new method of organization in business practices in the workplace and external relations.

Source: own study based on: Drucker, 2010; Peter 2011; Porter, 1990; Oslo Manual 2016.

2. Methodology/methods

Due to the prevailing empirical nature of the work it was decided to carry out the research based on two key research methods. The leading is the econometric analysis, (and therefore including the formulation of the econometric model and its estimation), but statistical analysis has also proved to be necessary (collection and interpretation of data describing the studied phenomenon).

Hypotheses:

1. The amount of expenditure on innovation activities of the companies depends directly on the GDP of individual Polish provinces.
2. The size of outlays for innovative activity is dependent on changes in the amount of internal expenditure on R&D.
3. The value of investment of Polish firms significantly affects the enhance of innovative activity.

Working hypotheses in the study were verified through the use of the ordinary least squares method. The software GNU Regression Econometric and Time-Series Library – GRETL, providing the necessary econometric methods, was used for the calculation of panel model.

3. Results and discussion

3.1. Model

The study will be conducted on a panel data - (seen at least in two dimensions, more Górecki, 2010). So, in this paper, an innovative activity of enterprises operating in the Polish provinces in 2008–2014 was examined. Assuming that the index i = 1, 2, ..., N determines more regions (provinces), and the index t = 1, 2, ..., T determines units of time (see Table 2), the constructed model has the form:

$$I_{it} = \alpha_{it} + GDP_{it} + (R+D_{it}) + INV_{it} + v_{it} \quad (1)$$

where:
I_i_t - dependent variable: expenditures on innovation activities of companies MILLION PLN explanatory variables:
GDP_i_t - GDP in current prices PLN MILLION
R+D_i_t - internal expenditure on R&D PLN MILLION
INV_i_t - investment in current prices PLN MILLION
αit - structural parameter of a model
vit - total random error (consisting of a purely random part εit and the individual effect ui, so vit = εit + ui) (Kufel, 2013).

Table 2. Assigning indexes to particular regions and periods

	i	t
1	Lower Silesia	2008
2	Kuyavia-Pomerania	2009
3	Lublin	2010
4	Lubus	2011
5	Lodz	2012
6	Lesser Poland	2013
7	Mazovia	2014
8	Opole	
9	Lower Carpathians	
10	Podlasie	
11	Pomerania	
12	Silesia	
13	Swietokrzyskie	
14	Varmia-Mazuria	
15	Greater Poland	
16	West Pomerania	

Source: own study.

In the empirical research statistical data drawn from the Local Data Bank (www.bdl.stat.gov.pl) was used. The data used are the unbalanced panel (more Franc-Dabrowska).

Outlays for innovative activity of the company became an explanatory variable. Due to the statistical confidentiality, in some cases, unfortunately, we failed to obtain data on the value of expenditures on innovative activities. So the model is unbalanced. The explanatory variables are the GDP at current prices, internal expenditure on R&D incurred in the unit and investment in enterprises.

3.2. The results of model estimation

The results of the model described above are shown in the following tables and charts, and the results of the most important and also the necessary tests are provided beneath (see Bukowski, 2012).

Table 3. OLS panel estimation using 72 observations

16 units of cross-sectional data were included
Time series length: minimum 4, maximum 7
The dependent variable (Y): I_i_t

	Factor	Student's t-	p-value	
const	−465,662	−2,4836	0,0148	**
GDP_i_t	−0,0176366	−2,6858	0,0085	***
R+D_i_t	1,52692	7,4637	<0,0001	***
Inv_i_t	0,38588	6,3404	<0,0001	***
The arithmetic mean of the dependent variable		2252,061	The standard deviation of the dependent variable	3257,159
The sum of squared residuals		77223203	The standard error of the residues	901,5963
Coefficient of determination R-square		0,925725	Adjusted R-squared	0,923379
F(3, 95)		394,6756	P-value of F test	1,75e-53
log-likelihood		−812,0459	Akaike information criterion	1632,092
Schwarz Bayesian Criterion		1642,472	Hannan-Quinn Criterion	1636,292
Autocorrelation of residues – rho1		0,304099	Durbin-Watson status	1,216367

*** variable statistically significant at the significance level of 0.01;
** variable statistically significant at the 0.05 level of significance;
* variable statistically significant at a significance level of 0.1.

Source: on the basis of the program GRETL.

The significance level for the three explanatory variables was 1%. It shows that as well as the GDP at current prices, internal expenditure on R&D incurred in the unit, and investment in enterprises are very strong factors influencing the expenditures incurred by the companies for innovative activity.

The coefficient of determination R-square indicates the extent to which the tested factor explains the specified dependent variable (Kufel, 2013). In this study, it operates at a level equal to 0.548287.

The test statistic: TR^2 = 54.280426, the value of p = P (Chi-square (9) > 54.280426) = 0.000000

Table 4. The frequency distribution

Intervals	mean	number	frequency	cumulative	
< -2614,8	-3106,7	1	1,01%	1,01%	
-2614,8 - -1631,0	-2122,9	1	1,01%	2,02%	
-1631,0 - -647,25	-1139,1	17	17,17%	19,19%	******
-647,25 - 336,52	-155,36	55	17,17%	74,75%	**********
336,52 - 1320,3	828,41	22	22,22%	96,97%	*******
1320,3 - 2304,1	1812,2	1	1,01%	97,98%	
2304,1 - 3287,9	2796,0	1	1,01%	98,99%	
3287,9 - 4271,6	3779,7	0	0,00%	98,99%	
≥ 4271,6	4763,5	1	1,01%	100,00%	

Source: based on the program GRETL.

Missing observations are at a level of 11.61%. Empirical cumulative distribution has a normal distribution for null hypothesis.

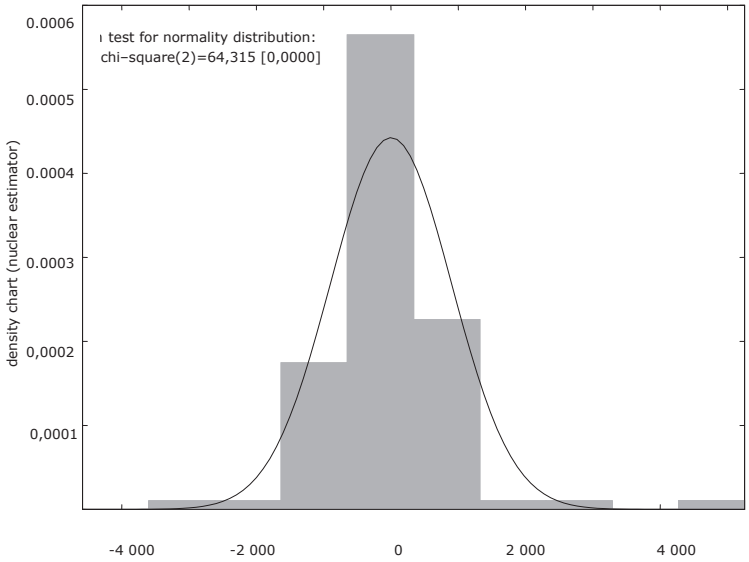

Figure 1. Test for normality distribution

Source: on the basis of the program GRETL.

The frequency distribution for uhat1, observations 1-112
the number of intervals = 9, mean = -3,9044e-013, standard deviation = 901.596

Collinearity rating VIF (j) - variance inflation factor
VIF (Variance Inflation Factors) - the minimum possible value = 1.0
Values > 10.0 may indicate a problem of collinearity - inflation of the variance
GDP_i_t 31,801
R+D_i_t 7,104
Inv_i_t 22,157

VIF(j) = 1/(1 - R(j)^2), where R(j) is the coefficient of multiple correlation between the variable 'j' and the other independent variables of the model.
To give a better sense of the problem, we also presented the results of panel estimation (least squares method) supplemented with additional variables 0-1 units of time.

Table 5. Panel OLS estimation using 99 observations
16 units of cross-sectional data were included
Time series length: minimum 4, maximum 7
The dependent variable (Y): I_i_t
Added variables: 0-1 units of time

	Factor	Standard error	Student's t-	p-value	
const	−921,502	268,403	−3,4333	0,0009	***
GDP_i_t	−0,0195573	0,00736414	−2,6558	0,0094	***
R+D_i_t	1,57842	0,201987	7,8145	<0,0001	***
Inv_i_t	0,402275	0,0702708	5,7246	<0,0001	***
dt_1	560,56	329,235	1,7026	0,0921	*
dt_2	592,359	331,874	1,7849	0,0777	*
dt_3	922,618	329,342	2,8014	0,0062	***
dt_4	382,219	314,388	1,2158	0,2273	
dt_5	687,067	344,611	1,9937	0,0492	**
dt_6	189,315	342,396	0,5529	0,5817	

The arithmetic mean of the dependent variable	2252,061	The standard deviation of the dependent variable	3257,159
The sum of squared residuals	68993696	The standard error of the residues	880,4601
Coefficient of determination R-square	0,933640	Adjusted R-squared	0,926930
F(9, 89)	139,1302	P-value of F test	1,78e-48
log-likelihood	−806,4680	Akaike information criterion	1632,936
Schwarz Bayesian Criterion	1658,887	Hannan-Quinn Criterion	1643,436
Autocorrelation of residues – rho1	0,305794	Durbin-Watson status	1,209672

Source: on the basis of the program GRETL.

Adding additional variables 0-1 units of time caused that the coefficient of determination R-square increased to a value of 0.959951.
The test statistic: TR ^ 2 = 95.035100, with a value of p = P (Chi-square (33) > 95.035100) = 0.000000

Table 6. The frequency distribution for uhat 4, observations 1-112
the number of intervals = 9, mean = 1,98665e-013, standard deviation = 880.46
Added variables: 0-1 units of time

Intervals	mean	number	frequency	cumulative	
< -2344,3	-2801,3	1	1,01%	1,01%	
-2344,3 - -1430,5	-1887,4	0	0,00%	1,01%	
-1430,5 - -516,60	-973,54	18	18,18%	19,19%	******
-516,60 - 397,27	-59,667	56	56,57%	75,76%	**********
516,60 - 1311,1	854,20	21	21,21%	96,97%	*******
1311,1 - 2225,0	1768,1	1	1,01%	97,98%	
2225,0 - 3138,9	2681,9	1	1,01%	98,99%	
3138,9 - 4052,7	3595,8	0	0,00%	98,99%	
≥ 4052,7	4509,7	1	1,01%	100,00%	

Source: on the basis of the program GRETL.

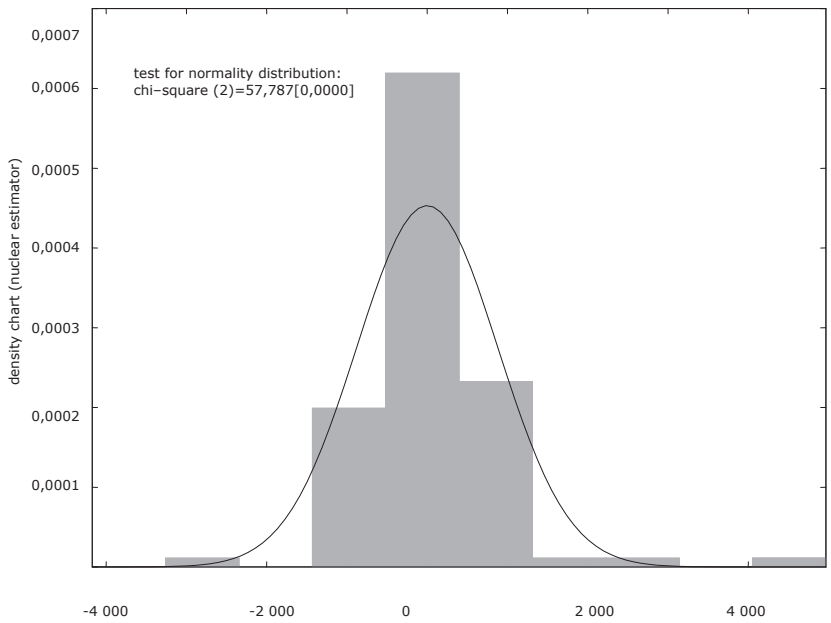

Figure 2. Test for normality distribution (with additional variables)
Source: on the basis of the program GRETL.

Collinearity rating VIF (j) - variance inflation factor
VIF (Variance Inflation Factors) - the minimum possible value = 1.0
Values > 10.0 may indicate a problem of collinearity - inflation of the variance
GDP_i_t 39,634
R+D_i_t 7,222
Inv_i_t 29,358
dt_1 1,889
dt_2 1,738
dt_3 1,778
dt_4 1,746
dt_5 1,776
dt_6 1,759
VIF(j) = 1/(1 - R(j)^2), where R(j) is the coefficient of multiple correlation between the variable 'j' and the other independent variables of the model.

The test results indicate that, the explanatory variables such as GDP and investment expenditure are correlated, and this indicates the presence of collinearity. Among the additional variables 0-1 units of time and in expenditure on research and development the phenomenon of collinearity does not appear , as specified numerical values are less than 10.

Table 7. Estimation Random effects (GLS), using 99 observations
16 units of cross-sectional data were included
Time series length: minimum 4, maximum 7
The dependent variable (Y): I_i_t
Added variables: 0-1 units of time

	Factor	Standard error	Student's t-	p-value	
const	732,665	251,474	2,9135	0,0045	***
GDP_i_t	0,0030833	0,00699776	0,4406	0,6605	
R+D_i_t	0,927435	0,262255	3,5364	0,0006	***
Inv_i_t	0,303809	0,059623	5,0955	<0,0001	***

Arithm. mean of depend. variable	2252,061	Stand. deviation of depend. variable	3257,159
The sum of squared residuals	85421398	The standard error of the residues	943,2954
log-likelihood	817,0403	Akaike information criterion	1642,081
Schwarz Bayesian Criterion	1652,461	Hannan-Quinn Criterion	1646,281

Source: on the basis of the program GRETL.

variance within' = 330317
variance between' = 132065

Breusch-Pagan Test on:
The null hypothesis: The variance of the error in the unit = 0
Asymptotic test statistic: Chi-square (1) = 5.17037 with a value of p = 0.0229754
Hausman test shows that for the null hypothesis UMNK estimator (GLS) is compatible. Asymptotic test statistic: Chi-square (3) is equal to 98.984 with a p value = 2,57006e-021.

Conclusions and recommendations

To sum up, the aim of the research was to analyze the relationship between changes in GDP, expenditures on R&D and capital expenditures and changes in the size of expenditure on innovation activities in 2008-2014. The panel model was built, annual data from the sixteen Polish provinces were used. Model estimation was made by classical least squares method using the program GRETL.

Results of the analysis presented in the work allow us to formulate the following conclusions:

- analysis of the panel is useful for solving problems related to exploration of determinants influencing the size of innovative activity in the surveyed provinces;
- the determinants of innovative activity should include all three examined factors. Increased level of these variables has a positive impact on changing the size of the innovative activity in Polish enterprises;
- the variability of the size of the innovative activity of Polish companies is affected, in a statistically significant way, by level of GDP and the level of expenditure on R&D (so the hypothesis 1 and 2 are confirmed);
- Hypothesis 3 was confirmed, since the value of investment is a direct factor increasing the size of outlays for innovative activity in the analyzed provinces in 2008-2014.

References

Bank Danych Lokalnych, www.bdl.stat.gov.pl [Access 23.09.2016]

Barbachowska, B. (2014). *Bariery innowacji w przedsiębiorstwie – stadium przypadku* [in:] A. Francik, M. Lis, V. Marakova (ed.), *Innowacje i przedsiębiorczość. Teoria i praktyka*, Dąbrowa Górnicza: Wyższa Szkoła Biznesu w Dąbrowie Górniczej, 53.

Bukowski, S. Gowers R. (2016). *The degree of integration of equity markets in Central Europe (new member EU countries) with the US and UK equity markets*. Central European Review of Economics & Finance, Vol. 11, No. 1.

Bukowski, S.I. (2012). *Rozwój rynków finansowych a wzrost gospodarczy w obszarze EURO-12*, Acta Universittatis Lodziensis, Folia Oeconomica 268, 44-52.

Drucker, P.F. (2010). *The Practice of Management*, HarperCollins.

Dyr, T., Ziółkowska K. (2014). *Economic infrastructure as factor of the region's competitiveness*. Central European Review of Economics & Finance, Vol. 6, No. 3.

Franc-Dąbrowska, J. *Praktyczne zastosowanie wybranych modeli panelowych do oceny sytuacji finansowej przedsiębiorstw rolniczych*, Warszawa: Szkoła Główna Gospodarstwa Wiejskiego. Artykuł przygotowany w ramach realizacji habilitacyjnego projektu badawczego pt. „Gospodarowanie zyskiem a sytuacja finansowa przedsiębiorstw rolniczych" N11300732/303, 31.

Francik, A. Szczepańska-Woszczyna, K., Dado J. (2016). *Procesy innowacyjne w polskiej gospodarce – potencjał zmian*, Dąbrowa Górnicza: Wyższa Szkoła Biznesu w Dąbrowie Górniczej.

Górecki, B. R. (2010). *Ekonometria podstawy teorii i praktyki*, Warszawa: Wydawnictwo Key Text, 17.

Górka, M. (2014). *Innowacyjna gospodarka – mit czy rzeczywistość* [in:] Górka, M., Pogonowski, M. (ed.), *Współczesny wymiar administracji publicznej. Polityka społeczna. Bezpieczeństwo publiczne Innowacyjność. Transparentność*, Koszalin: Wydawnictwo Uczelniane Politechniki Koszalińskiej.

Klóska, R. (2015). *Innowacyjność jako determinant rozwoju regionalnego w Polsce*, Szczecin: Wydawnictwo Naukowe Uniwersytetu Szczecińskiego.

Kristofik, P., Lament, M., Musa, H., Wolak-Tuzimek, A. (2015). *Financial tools in management of small and medium-sized enterprises*, London: Sciemcee Publishing, 189-197.

Kufel, T. (2013). *Ekonometria. Rozwiązywanie problemów z wykorzystaniem programu GRETL*, Wydanie trzecie, zmienione, Warszawa: Wydawnictwo Naukowe PWN, 173.

Oslo Manual (2016), *Guidelines for Collecting and Interpreting Innovation Data*, OECD http://www.oeced.org, dostęp 24.09.2016

Peter, J. (2011). *Innovationscontrolling: Der Einsatz von Kennzahlen und Kennzahlen-systemen*, Hamburg: Diplomica Verlag GmbH.

Porter, M.E. (1990). *The Competitive Advantage of Nations*, London: The Macmillan Pres Ltd.

Schumpeter, J. (1939). *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, New York – London: McGraw-Hill, 84.

Wolak-Tuzimek, A. (2016). *Benefits of introducing the concept of corporate social responsibility to enterprises*. Central European Review of Economics & Finance, Vol. 14, No. 4.