Relative Index of Enterprise Innovation Activity for Polish provinces

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Abstract

The aim of the paper is to propose the Relative Index of Enterprise Innovation Activity for Polish provinces. Calculations are based on data published in "Innovation activity of enterprises in 2013-2015" (Polish Central Statistical Office), which comes from the shorter version of Community Innovation Survey. Partial indexes are calculated for investments in innovation, innovation activities, public support, cooperation in innovations and economic results, separately for industry and services, and finally the global index is presented. Indexes are calculated with classical approach assuming normalization of variables into [0;1] interval and averaging them. A new iterative method which finds the best objects one by one starting from top of the ranking is also used. Variables are subject to three types of weights, one based on their hierarchical structure and one established by panel experts.

Key words: *innovations, composite index, Polish provinces*

JEL Classification: C19, O31, R11.

1 Introduction

Problems connected with innovativeness are considered on country economic level – macro scale, regional level – mezzo scale, and smaller spatial units (e.g. cities) – micro scale (Audretsch, 1998). This classification is based on territory, which just by its spatial existence does not determine the innovativeness which is understood as „the process of translating an idea or invention into a good or service that creates value or for which customers will pay. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. Innovation involves deliberate application of information, imagination and initiative in deriving greater or different values from resources, and includes all processes by which new ideas are generated and converted into useful products. In business, innovation often results when ideas are applied by the company in order to further satisfy the needs and expectations of the customers"[3]. Creative and inventive personnel decide if new product, service, process, marketing or organizational solution is born on a given territory (Löfsten, 2014). The idea, the exchange of thoughts and experience, the contact network, and

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[3] http://www.businessdictionary.com/definition/innovation.html.

innovation environment are needed for the creative destruction, as innovations were called by P. Drucker (1984), (Branstetter and Sakakibara, 2002).

In literature, we can find factors (Fukugawa, 2006), barriers (Hadjimanolis, 1999; Piattier, 1984), sources (Riggs and von Hippel, 1994) and determinants of innovations (Mohr, 1969; Romjin and Albaladejo, 2002). To measure this phenomenon we need methods (OECD, 2005), and indexes (Tadeu and Silva, 2014), which are being changed in time. Different set of measures were developed for the whole economy (Lundstorm et al., 2008), and different for innovativeness of firms (Kirner et al., 2008). There are descriptive and mathematical models trying to illustrate such complicated phenomenon as innovativeness. Rankings for countries and regions are developed based on sets of variables which measure innovation processes.

2 Method

The aim of the paper is to propose the Relative Index of Enterprise Innovation Activity for Polish Provinces. All variables used, are subject to transformation into [0;1] interval with the following formula:

$$x_i^* = \frac{x_i - \min_i \{x_i\}}{\max_i \{x_i\} - \min_i \{x_i\}}$$

All our variables are stimulants (”the bigger, the better”), so one transformation formula is enough. The proposed index is *relative* because variables are transformed using minimal and maximal values observed in the set of 16 Polish provinces. The value of a composite index shows the innovation level in relation to all other provinces, and not to the „objective” reference points. The classical composite index based on m variables, is a weighted (with w_j weights) arithmetic average of transformed variables:

$$RI_i = \frac{s\sum_{j=1}^{m} w_j x_{ij}^*}{\sum_{j=1}^{m} w_i}.$$

It takes values from [0;s] interval, while s is usually assumed as 1, 100, or 1000. The classical composite index is non-robust against outliers or very skewed distributions of individual variables. Outliers used as reference points introduce some kind of unwanted weighting system. Sokołowski and Markowska (2017) proposed a new iterative method for ranking multivariate object and calculating composite index. In the first step the best object is found, and got the rank number one. Then it is eliminated from the set searched for object number two, and so on, assigning just one rank at a time. Reference points (minimum and

maximum) are selected from the set of objects not ranked yet, so we are looking for the best object out of those which are left to be ranked. The composite index is then calculated as:

$$RII_{(k)} = I^{1}_{(1)} \prod_{l=2}^{k} \frac{l^{l-1}_{(l)}}{l^{l-1}_{(l-1)}}$$

where:

$RII_{(k)}$ – relative iterative index for *k-th* ordered object,

l – rank (iteration number),

I^l – composite index obtained in l-step of the procedure.

We can see that the composite index for the best object is the same for classical and iterative procedures. Next values of *RII* are smaller by the ratio of local (for a given step) index values calculated for the latest step, when two consecutive objects where both considered.

3 Variables

Variables measuring innovations have been taken from the Central Statistical Office publication *"Innovation activity of enterprises in 2013-2015"* (Innovation, 2016), which comes from the shorter version of Community Innovation Survey. Partial indexes are calculated for:

– I – investments in innovation (0.23),

– S – public financial support (0.09)

– A – innovation activities (0.24),

– C – cooperation in innovations (0.19),

– R – economic results (0.26),

separately for industry and services, and finally the global index is presented. There are three systems of weights. The first one comes from the hierarchical structure of variables. We have three levels of them and generally each lower level has the weight which is half of the upper level, and this weights are divided among homogeneous variables on the same level. The second weighting system for five innovation aspects mentioned above (weights are in brackets) is based on weights assigned individually by 10 experts. Finally, indexes for industry and services are joined with equal weights for global relative innovation index. The list of variables which is given in Table 1, is the same for both industry and services, as well as the first weighting system presented in the last column. Percentage of innovation active enterprises in industry is the lowest in Świętokrzyskie (14.5), and the highest in Opolskie (23.1). This range in services is between 6.6 (Warmińsko-Mazurskie) and 13.6 (Zachodniopomorskie).

	Variable	Industry		Services		Weight
		Range	Poland	Range	Poland	
I	Enterprises investing in innovations	10.9-16.4	14.0	4.6-11.1	7.4	1.00
I	Average innovation investments per enterprise in 1000's PLN	356-1362	968	19-1425	479	1.00
S	Enterprises receiving public financial support	3.6-7.5	4.9	0.6-4.1	2.1	1.00
S	Enterprises receiving public financial support from domestic institutions	1.6-4.9	2.7	0.4-3.5	1.4	0.50
S	Enterprises receiving public financial support from local authorities	0.4-2.1	1.0	0.0-2.3	0.8	0.25
S	Enterprises receiving public financial support from central authorities	1.1-3.0	1.9	0.2-3.5	0.8	0.25
S	Enterprises receiving public financial support from EU	2.5-5.9	3.7	0.3-3.9	1.5	0.50
S	Enterprises receiving public financial support from Horizon 2020	0.0-1.3	0.4	0.0-1.1	0.2	0.25
A	Innovation active enterprises	14.5-23.1	18.9	6.6-13.6	10.6	1.00
A	E.w.i.* innovations	13.7-21.5	17.6	6.3-13.0	9.8	1.00
A	E.w.i. new products	9.6-14.4	11.8	2.8-7.6	4.8	0.50
A	E.w.i. new processes	6.8-13.8	9.9	0.3-5.0	2.3	0.17
A	E.w.i new logistics	1.8-4.7	3.2	0.7-3.9	2.7	0.17
A	E.w.i supporting activities	4.0-7.5	5.9	2.3-8.8	5.4	0.17
A	E.w.i organisational or marketing innovations	8.2-16.3	11.4	2.7-18.1	10.7	1.00
A	E.w.i organisational innovations	5.3-10.5	8.1	2.3-15.2	8.1	0.50
A	E.w.i new business practices for organisational procedures	3.6-8.2	6.1	0.9-7.8	4.0	0.17
A	E.w.i. new methods in work responsibilities	2.8-7.9	5.0	1.6-9.3	5.5	0.17
A	E.w.i. new methods in external relations	1.9-4.7	3.1	0.5-7.2	3.5	0.17
A	E.w.i. marketing innovations	4.7-12.5	7.1	1.6-11.5	6.6	0.50
A	E.w.i. new packaging	2.6-9.0	4.2	0.4-3.9	2.2	0.13

A	E.w.i. new media and promotion	1.7-6.8	3.8	1.1-7.9	4.2	0.13
A	E.w.i. new product placement and sales	1.1-3.7	2.1	0.4-4.8	2.6	0.13
A	E.w.i. new pricing	1.4-5.4	2.7	0.8-6.1	3.2	0.13

[*] – *Enterprises which introduced*

Table 1. List of variables – part 1.

	Variable	**Industry**		**Services**		**Weight**
		Range	**Poland**	**Range**	**Poland**	
C	Enterprises cooperating	3.7-8.4	5.5	1.0-4.8	2.6	1.00
C	Enterprises cooperating for receiving access to intellectual property	0.1-0.3	0.2	0.2-1.3	0.6	0.17
C	Enterprises benefiting from free intellectual property	0.7-2.7	1.4	1.0-3.5	2.4	0.17
C	Enterprises using innovations protected by exclusive rights	1.6-3.7	2.3	0.5-4.7	2.4	0.17
R	Revenues from products to the market	3.6-18.3	9.5	0.3-5.1	3.0	0.50
R	Revenues from products new to the firm	1.1-13.1	5.5	0.0-2.9	1.7	0.50
R	Enterprises with applications for trademarks in Poland	0.4-6.5	3.0	0.7-5.4	3.2	1.00
R	Enterprises with applications for industrial designs in Poland	0.5-5.3	1.3	0.2-1.2	0.4	1.00
R	Enterprises with applications for utility models in Poland	0.2-3.3	1.0	0.0-1.4	0.3	1.00
R	Enterprises with applications for patents in Poland	1.2-4.6	2.3	0.1-1.9	0.7	1.00
R	Enterprises planning to apply for foreign patents	0.1-2.8	0.6	0.1-1.5	0.3	0.50
R	Enterprises with Polish patent applications resulted from internal R&D activities	1.1-3.7	1.6	0.2-1.9	0.6	0.50
R	Enterprises which obtained patents in Poland	1.0-4.9	2.0	0.2-2.7	1.4	1.00
R	Enterprises which made application for foreign patent	0.3-3.4	1.0	0.1-2.6	0.5	1.00

R	Enterprises which obtained foreign patents	0.1-3.0	0.7	0.0-1.2	0.3	1.00

Table 2. List of variables – part 2.

4 Results

For all indexes a value of s=1000 has been used. Indexes for industry and services are both based on 39 variables each, subject to weights for individual variable weights (Table 1 and 2) and expert weights. Global index comes as simple average from industry and services indexes. Values of indexes are given in Table 3 and ranks in Table 4.

Province	Classical Index			Iterative Index		
	Industry	Services	Global	Industry	Services	Global
Dolnośląskie	537	636	587	503	636	570
Kujawsko-pomorskie	258	217	238	233	239	236
Lubelskie	324	240	282	262	217	240
Lubuskie	256	187	221	200	222	211
Łódzkie	236	440	338	214	389	302
Małopolskie	490	386	438	488	399	444
Mazowieckie	467	730	598	468	730	599
Opolskie	503	183	343	481	186	334
Podkarpackie	620	542	581	582	520	551
Podlaskie	639	215	427	639	157	398
Pomorskie	318	311	314	324	346	335
Śląskie	591	263	427	591	298	445
Świętokrzyskie	108	246	177	92	199	146
Warmińsko-mazurskie	287	108	197	253	96	175
Wielkopolskie	358	186	272	365	227	296
Zachodniopomorskie	379	381	380	370	323	347

Table 3. Values of Relative Index of Enterprise Innovation Activity (RIEIA).

Values of classical and iterative indexes are of course very highly correlated – r=0.992 for industry, r=0.981 for services, and r=0.988 for global index. On Fig. 1 we can see that three provinces are the best in enterprise innovation activity. They are Mazowieckie, Dolnośląskie

and Podkarpackie. Podlaskie which came first in industry was just 15th in services. Their leading positions are the same in classical and iterative rankings.

Correlations between two methods are high, but the changes in rankings are important. 7 out of 16 provinces changed their position in iterative methods comparing to classical one (See Fig. 2). Pomorskie went up two positions, Śląskie and Wielkopolskie by one position, while four provinces went down just one position: Lubelskie, Łódzkie, Małopolskie, and Opolskie.

Province	**Classical Index**			**Iterative Index**		
	Industry	**Services**	**Global**	**Industry**	**Services**	**Global**
Dolnośląskie	4	2	2	4	2	2
Kujawsko-pomorskie	13	11	13	13	9	13
Lubelskie	10	10	11	11	12	12
Lubuskie	14	13	14	15	11	14
Łódzkie	15	4	9	14	5	10
Małopolskie	6	5	4	5	4	5
Mazowieckie	7	1	1	7	1	1
Opolskie	5	15	8	6	14	9
Podkarpackie	2	3	3	3	3	3
Podlaskie	1	12	6	1	15	6
Pomorskie	11	7	10	10	6	8
Śląskie	3	8	5	2	8	4
Świętokrzyskie	16	9	16	16	13	16
Warmińsko-mazurskie	12	16	15	12	16	15
Wielkopolskie	9	14	12	9	10	11
Zachodniopomorskie	8	6	7	8	7	7

Table 4. Ranks for provinces.

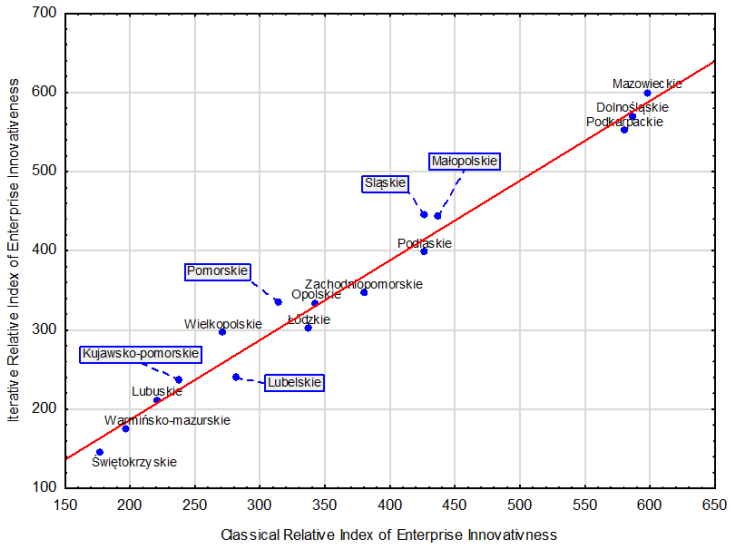

Fig. 1. Scatter diagram for provinces based on classical and iterative innovation indexes.

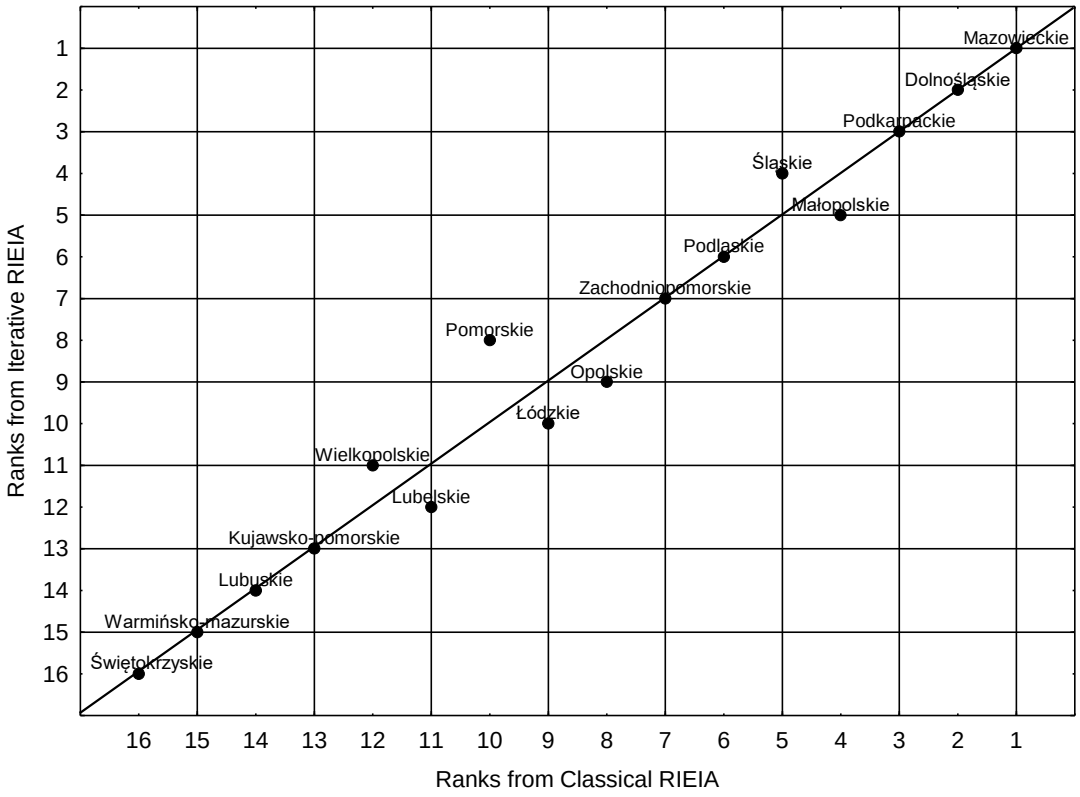

Fig. 2. Ranks based on classical and iterative innovation indexes.

What we found interesting is, a lack of correlation between industry and services. Fig. 3 illustrate the situation for iterative index. For classical one, the correlation is also nonsignificant (r=0.182; p=0.1815).

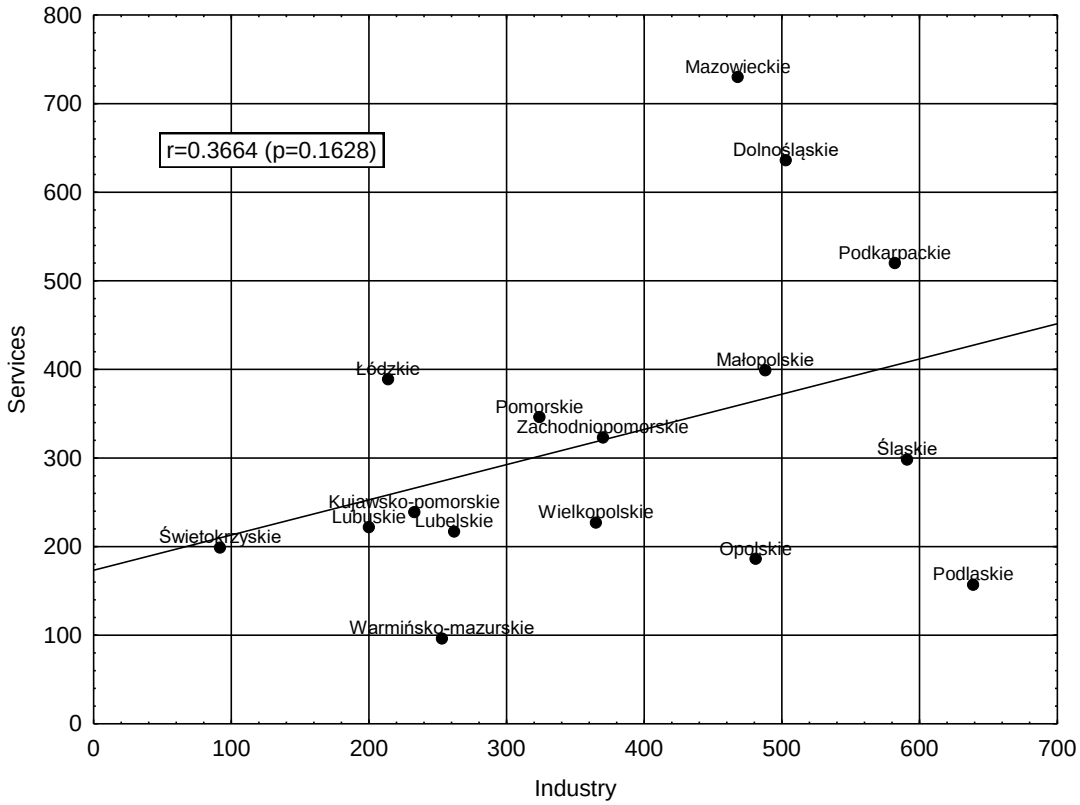

Fig. 3. Correlation of iterative indexes.

Conclusions

The main purpose of this paper was to introduce Relative Index of Enterprise Innovation Activity for Polish Provinces. The list of variables is always a matter for discussion, but the one we proposed is everything what could be extracted from mentioned Central Statistical Office publication on regional (NUTS 2) level. Iterative method seems to be the good choice since it is robust against outlying objects. It is interesting to find that innovation processes in industry and services look as uncorrelated.

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