Roszko-Wojtowicz, Elzbieta; Bialek, Jacek

Working Paper

Application of the PROperty FITting Method (PROFIT) to Classification of EU Countries Based on Their Innovation Level

Institute of Economic Research Working Papers, No. 103/2017

Provided in Cooperation with:
Institute of Economic Research (IER), Toruń (Poland)

Suggested Citation: Roszko-Wojtowicz, Elzbieta; Bialek, Jacek (2017) : Application of the PROperty FITting Method (PROFIT) to Classification of EU Countries Based on Their Innovation Level, Institute of Economic Research Working Papers, No. 103/2017, Institute of Economic Research (IER), Toruń

This Version is available at:
https://hdl.handle.net/10419/219925

Institute of Economic Research Working Papers

No. 103/2017

Application of the PROperty FITting Method (PROFIT) to Classification of EU Countries Based on Their Innovation Level

Elżbieta Roszko-Wójtowicz, Jacek Białek

Article prepared and submitted for:

9th International Conference on Applied Economics Contemporary Issues in Economy, Institute of Economic Research, Polish Economic Society Branch in Toruń, Faculty of Economic Sciences and Management, Nicolaus Copernicus University, Toruń, Poland, 22-23 June 2017

Toruń, Poland 2017

Application of the PROperty FITting Method (PROFIT) to Classification of EU Countries Based on Their Innovation Level

Elżbieta Roszko-Wójtowicz[1], Jacek Białek[2]

Abstract

Research background: As it is known, innovativeness can be measured by using many known indices, such as the Global Innovation Index, the Summary Innovation Index, etc. and often these indices are based on different methodologies and take into consideration different sets of diagnostic variables. As a consequence, the final evaluation of innovativeness may strongly depend on the innovation index used. Obviously, some groups of indices lead to similar ranks of the EU countries. Nevertheless, if there are at least two groups of indices which provide different ranks of these countries, a problem with the proper evaluation of their real innovativeness arises. One of the solutions is to select the most valuable indices by observing the impact of all indices on forming distances between innovativeness levels of the EU countries. Following this option, the main aim of this paper is classification of the EU countries with respect to their innovativeness and the evaluation of international index influences on the classification obtained.

Purpose of the article: The aim of the paper is to conduct the research on differences in innovation intensity across the EU member countries.

Methodology/methods: For the purpose of the article, the PROFIT (PROperty FITting) method, an extension of multidimensional scaling (MDS), was applied. The ultimate goal of MDS techniques is to produce a geometric map that illustrates the underlying structure of complex phenomena, for instance, innovativeness of the EU countries. It is a widely used method which collects attribute ratings for each object (country) and then finds the best correspondence of each attribute to the derived perceptual space. Applying the PROFIT method needs linear regression techniques and provides some additional information, i.e. the impact of the considered set of diagnostic variables on the shape of the perception map.

Findings & Value added: The final result is a two-dimensional map of the EU countries which reflects distances among their innovativeness levels along with vectors presenting the influence of international indices of innovativeness on the structure of this map. The nature of the results and the ways in which they are

[1] University of Łódź, Institute of Statistics and Demography 90-255 Łódź, 3/5 POW Street, e-mail: eroszko33@gmail.com,

[2] University of Łódź, Institute of Statistics and Demography 90-255 Łódź, 3/5 POW Street, e-mail: jbialek@uni.lodz.pl

interpreted are subsequently reviewed. The main conclusion drawn from the perception map created concerns the interpretation of the above-mentioned vectors, i.e. the information about the role of each international innovation index in clustering the EU countries with respect to their innovation intensity is obtained.

JEL Classification: *A11; A14; B16*

Keywords: multidimensional *scaling (MDS), property fitting method (PROFIT), innovation intensity, EU member countries, synthetic measures of innovativeness*

Introduction

As it is known, innovativeness can be measured by using many known indices, such as the *Global Innovation Index* (Dutta *et al.*, 2015), the *Summary Innovation Index* (European commission, 2015), and also the *Innovation Output Indicator* recently added by the European Commission (European Commission 2013; Vertesy & Deiss, 2016), as well as many others. Often these indices are based on different methodologies and take into consideration different sets of diagnostic variables. As a consequence, the final evaluation of innovativeness may strongly depend on the innovation index used.

Sources of public statistical data play an important role in (1) the process of development of a proper national policy aimed at ensuring economic and social progress, and (2) the measurement and evaluation of phenomena occurring in the modern world. In the last few decades, the role and importance of statistics, especially indices of measurement, have significantly increased (Giovannini & Uysal, 2006). Public interest in information is based on current needs and is directly connected with people's active participation in various decision-making processes, both in the public and private domain (Hahn & Doganaksoy, 2008). This particular explosion of information often, instead of facilitating, becomes a considerable obstacle. Questions are raised about the quality and form of the information provided, its validity and reliability, thus further dilemmas are born (Goldsmith & Foxall, 2003, pp. 321-330; Hollanders, Van Cruysen, 2008). One of the solutions is to select the most valuable indices by observing the impact of all indices on forming distances between innovativeness levels of the EU countries. Following this option, **the main aim of this paper** is classification of the EU countries with respect to their innovativeness and the evaluation of international index influences on the classification obtained. In reference to the aim of the paper, a research hypothesis has been formulated stating that the degree of specialisation of an innovation index has a significant influence on the location/position of the EU Member States on a perceptual map. For the purpose of the analysis

conducted, it has been assumed that the type and number of variables and the number of partial aggregates (sub-indices) included in the construction of the final innovation index determine the degree of index specialisation.

For the purpose of the article, the PROFIT (PROperty FITting) method, an extension of multidimensional scaling (MDS), was applied. Multidimensional scaling is used in many different fields, including economics (e.g.: Black 1991), sociology (e.g: Beardsworth & Keil 1992) and political science, as well as many other disciplines. Multidimensional scaling is widely used to assess various socioeconomic events, ranging from social/human views (Wish, Deutsch, & Biener 1971) to perceptions of visual patterns (Hirschberg, Jones, & Haggerty, 1978).

Methodology

The Concept of the Analysis

The research procedure was carried out according to the following steps: Step 1) Due to the varying range of variation of the innovation indices – *SII*, *IOI* and *GII* – selected for the analysis, first the standardisation of the variables according to the scheme corresponding to the zero unitarisation method was carried out. Step 2) Then multidimensional scaling was performed using the Euclidean distance, thus reducing the number of dimensions to two. Step 3) The last stage was the estimation of regression model parameters according to the PROFIT concept.

As a result of activities carried out within the framework of the above-described statistical procedure, a perceptual map was obtained illustrating similarities of the EU countries in terms their level of innovativeness and showing how individual innovation indices have contributed to the position of the individual countries on the map (Fig. 1).

Research Method

PROFIT (PROperty FITting) is a kind of external vector analysis of preference mapping. The standard reason for using this method is testing hypotheses about attributes that influence people's judgement of similarities among a set of items. Nevertheless, there are no technical objections to using PROFIT for other cases, not related only to human preferences. The PROFIT method is a two-step procedure which is a combination of multidimensional scaling and multiple regression analysis. To understand the idea of PROFIT, it is advisable to start from the description of multidimensional scaling (MDS). Multidimensional scaling (MDS) is a means of visualising the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in information visualisation, in particular, to display the information contained in a distance matrix. It is a form of non-linear dimensionality

reduction (Kruskal & Wish, 1978), Young & Hamer, 1987). An MDS algorithm aims to place each object in *N*-dimensional space so that the between-object distances are preserved as well as possible. Each object is then assigned coordinates in each of the *N*-dimensions. The number of dimensions of an MDS plot *N* can exceed 2 and is specified a priori. Choosing *N*=2 optimises the object locations for a two-dimensional scatterplot. MDS can have a metric or non-metric form and, as a rule, the non-metric MDS is used before the PROFIT analysis (Kruskal, 1964, Takane *et al.*, 1977). In such a case, the method finds both a non-parametric monotonic relationship between the dissimilarities in the item-item matrix and the Euclidean distances between items, and the location of each item in the low-dimensional space. The relationship is typically found using isotonic regression: let denote the vector of proximities, – a monotonic transformation of and the point distances; then coordinates have to be found that minimise the so-called *stress* defined as follows

(Kruskal, 1964): , (1)

where lower indexes denote the *i* – th and the *j* – th point on MDS map.

A PROFIT analysis evaluates the correspondence between one or more item attributes and the location of items in a multidimensional space. As it was above-mentioned, PROFIT, which is a combination of multidimensional scaling and multiple regression analysis, consists of two phases. After the first step (MDS), we obtain a configuration of *n* points $x = (x_1, x_2, \ldots, x_n)^T$ in *r* – dimensional space (*r* is usually 2 or 3). In the second phase, PROFIT takes as input both a configuration of points *x* and a set of attribute preferences data $p_k = (p_{k1}, p_{k2}, ..., p_{kn})^T$, where $k = 1,2, ..., m$, is a number of attributes (Zaborski & Pełka, 2013). Then a multiple regression analysis is performed using the coordinates of as independent variables and the attributes as dependent variables. The procedure provides a separate regression for each attribute with "classical" regression coefficients:

. (2)

Results and Discussion

Research Data

In this section, selected synthetic indices of innovativeness will be presented. The analysis conducted was limited to three major indices, i.e.

the *Global Innovation Index*, the *Summary Innovation Index and* the *Innovation Output Indicator*. Differences in the approach to the measurement of innovativeness in each of these indices have a significant impact on the final results of the ranking of countries. One of the fundamental differences that can be observed is the degree of specialisation of the innovation indices selected for the analysis. The comparative summary of these three innovation indices presents the table below.

Table 1. Comparative summary of selected indices

No.	Name of the indicator	Source	Number of variables	Number of countries	Data of publication
1.	Global Innovation Index	Business School of the World, the World Intellectual	79	141	Since 2007, annually
2.	Innovation Output Indicator	European Commission	5	38	Since 2010, 4-year time frame
3.	Summary Innovaiton Index	European Commission	25	34	Since 2001, annually

Source: own elaboration based on: European Commission (2013), European Commission (2015), Vertesy & Deiss (2016), Dutta *et al*., (2015).

The *Global Innovation Index* is characterised by the broadest coverage of variables. The eighth edition of the report presented 141 economies, the study covered 95.1% of the population living worldwide and 98.6% of global GDP (US $). In the construction of the ranking, 79 individual indicators that characterised innovativeness were included (Dutta *et al*., 2015).

It is followed by the *Summary Innovation Index*. As with *GII*, sub-indices, made up of a specific number of variables, are also created for this index. Over the years, the methodology of calculating the *SII* has evolved, now 25 indicators, which have been assigned to one of the five categories, are used. The first three sets of indicators are variables from the input layer, and the last two from the output layer. The input layer is described by: a) factors stimulating innovativeness (enablers), b) firm activities which show innovative activities implemented at the company level. The output layer is described by effects which reflect the results of innovative activities carried out in the sphere of business (European Commission, 2015; Majerova, 2015, pp. 230-231).

The *Innovation Output Indicator* is undoubtedly the index characterised by the narrowest specialisation among the ones chosen for the comparative analysis. Only five variables can be isolated in the index, and only in one case, at a lower level of analysis, an aggregate variable is generated. This applies to competitiveness of knowledge-intensive industries (with a high

demand for specialist knowledge). The COMP component is defined as the arithmetic average (with equal weights) of two indicators: GOOD – the total value of exports of a country and SERV – the share of knowledge-intensive services in total services exports (European Commission, 2013, pp. 1-2).

Research Results

In the paper, the PROFIT analysis is used to show how an input set of attributes (the values of the individual innovation indices) of the objects (the EU Member States) is visualised on the multidimensional scaling axes. Coordinates assigned to the individual objects (countries) are considered as explanatory (independent) variables, while the values of individual attributes (innovation indices) of the objects are response (dependent) variables.

In the presented example, three regression analyses were performed as three attributes (variables) – *SII*, *GII*, *IOI* – were included in multidimensional scaling. The coordinates of the individual attributes (variables) were determined with the use of standardised regression coefficients corresponding to each of the multidimensional scaling axes. After conducting the regression analyses for all the three innovation indices, the PROFIT analysis algorithm provides directional correlation coefficients determining the vector direction and sense that corresponds to each of the attributes selected to describe the dimensions. Thus three points with the following coordinates were determined on the MDS map: *SII* (Dim 1 – (0.978); Dim 2 – (0.036)), *GII* (Dim 1 – (0.959); Dim 2 – (-0.269)), and *IOI* (Dim 1 – (0.941); Dim 2 – (0.298)); detailed results are presented in Table 2. The determined coordinates for the individual attributes allow to show how the EU member countries are arranged according to the intensity of a given attribute.

Figure 1. The perceptual map with vectors describing the individual dimensions of the plane.

Note: The calculations were made with the use of Statistica 12.5 software Plus Suite – specialist analytical package.
Source: own elaboration based on: European Commission (2013), European Commission (2015), Vertesy & Deiss (2016), Dutta *et al*., (2015).

Figure 2. Shepard diagram illustrating the distances derived from the original data sources versus the distances reproduced in the MDS analysis.

Note: The calculations were made with the use of Statistica 12.5 software Plus Suite – specialist analytical package.

Source: own elaboration based on: European Commission (2013), European Commission (2015), Vertesy & Deiss (2016), Dutta *et al*., (2015).

The Shepard diagram, which confronts distances based on the original data source with distances visualised in the MDS analysis (Fig. 2), and the low value of *stress* = 0.0188 indicate high efficiency of multidimensional scaling. In turn, the relevance of almost all the regression coefficients determined in the second stage of the PROFIT method and very high match rates of regression models (Tab. 2) indicate that the interpretation of the vectors determined on the perceptual map (Fig. 1) is probably reflected in reality.

Table 2. Regression analysis for all the variables/dimensions of the evaluation.

N = 28	**Regression results for *IOI*:** R^2= 0.9738; corrected R2= 0.9717					
	F(2.25)=465.24 p<0.0000 Estimation error: 0.04774					
	b*	**std.error b***	**b**	**std.error b**	**t(25)**	**p**
free coeff.			0.498151	0.009021	55.21899	0.000000
Dim 1	0.949745	0.032351	0.269757	0.009277	29.07926	0.000000
Dim 2	0.298052	0.032351	0.356765	0.038724	9.21304	0.000000
N = 28	**Regression results for *SII*:** R^2= 0.9584; corrected R^2= 0.9551					
	F(2.25)=288.19 p<0.00000 Estimation error: 0.06366					
	b*	**std.error b***	**b**	**std.error b**	**t(25)**	**p**
free coeff.			0.513552	0.012031	42.68748	0.000000
Dim 1	0.978316	0.040778	0.296794	0.012371	23.99132	0.000000
Dim 2	0.036412	0.040778	0.046112	0.051641	0.89295	0.380402
N = 28	**Regression results for *GII*:** R^2= 0.9928; corrected R^2= 0.9923					
	F(2.25)=1746.5 p<0.0000 Estimation error: 0.02753					
	b*	**std.error b***	**b**	**std.error b**	**t(25)**	**p**
free coeff.			0.491315	0.005202	94.4393	0.000000
Dim 1	0.959316	0.016860	0.304392	0.005350	56.8995	0.000000
Dim 2	-0.269457	0.016860	-0.356904	-15.9822	0.89295	0.000000

Note: The calculations were made with the use of Statistica 12.5 software Plus Suite – specialist analytical package.
Source: own elaboration based on: European Commission (2013), European Commission (2015), Vertesy & Deiss (2016), Dutta *et al*., (2015).

The analysis of the position of each country on the perceptual map (see: Fig. 1 and Tab. 3) allows to draw some detailed conclusions about similarities and differences between the EU countries from the point of view of the indications of the 3 analysed indices of innovativeness. A clear advantage of the PROFIT method is the fact that, despite a fairly complex calculation procedure, it enables an easy and clear interpretation of the results presented graphically. When analysing the results obtained, it should be noted that the position of the EU country described by coordinates on

the perceptual map is influenced by all the variables included in the analysis, i.e. all the three innovation indices combined. It can therefore be seen that, for example, Germany and Denmark are characterised by the highest intensity of *IOI* value. The reproduction of the coordinates for Lithuania and Latvia on the line where the IOI vector lies indicates that these countries have the worst results in terms of the variable in question. On the other hand, the Netherlands, the United Kingdom, and Sweden achieve the highest results according to the *Global Innovation Index*. In relation to *SII*, the ranking of the Member States shows that Sweden, Germany, Denmark, and Finland are characterised by the highest intensity of innovation index values, while Lithuania, Bulgaria, Latvia, and Romania by the lowest intensity.

Table 3. The results of the PROFIT analysis along with the coordinates that determine the location of each country on the perceptual map.

	Final configuration: Stress = 0.018				
	GII	***IOI***	***SII***	**Dim 1**	**Dim 2**
Austria	0.655	0.636	0.711	0.577	-0.025
Belgium	0.525	0.556	0.775	0.411	0.199
Bulgaria	0.164	0.112	0.046	-1.356	-0.138
Croatia	0.145	0.154	0.203	-1.127	-0.065
Cyprus	0.219	0.375	0.449	-0.517	0.198
Czech Republic	0.542	0.480	0.453	-0.043	-0.146
Denmark	0.805	0.855	0.993	1.314	0.193
Estonia	0.603	0.359	0.531	0.014	-0.311
Finland	0.899	0.871	0.881	1.319	0.005
France	0.635	0.719	0.721	0.654	0.096
Germany	0.778	1.000	0.881	1.323	0.325
Greece	0.086	0.277	0.299	-0.963	0.193
Hungary	0.198	0.515	0.308	-0.590	0.394
Ireland	0.864	0.884	0.791	1.194	0.026
Italy	0.339	0.398	0.438	-0.380	0.062
Latvia	0.302	0.089	0.127	-1.108	-0.350
Lithuania	0.168	0.000	0.146	-1.338	-0.315
Luxembourg	0.860	0.882	0.817	1.201	0.035
Malta	0.507	0.406	0.359	-0.264	-0.199
Netherlands	0.965	0.566	0.827	0.987	-0.507
Poland	0.081	0.355	0.202	-1.011	0.290
Portugal	0.347	0.184	0.371	-0.673	-0.264
Romania	0.000	0.304	0.000	-1.428	0.347
Slovakia	0.198	0.419	0.291	-0.704	0.236
Slovenia	0.425	0.445	0.615	-0.017	0.119
Spain	0.449	0.345	0.338	-0.423	-0.182
Sweden	0.999	0.973	1.000	1.667	0.013
United Kingdom	1.000	0.791	0.807	1.282	-0.230

Note: The calculations were made with the use of Statistica 12.5 software Plus Suite - specialist analytical package.

Source: own elaboration based on: European Commission (2013), European Commission (2015), Vertesy & Deiss (2016), Dutta *et al*., (2015).

Conclusions

The quality and reliability of the results obtained can be deemed as high, which may arise from the fact that dimensionality reduction was not too drastic and meant the transition from 3 dimensions (3 innovation indices) to 2 dimensions which are easy to interpret on the Cartesian perceptual map. The PROFIT analysis brings additional benefits beyond the ranking, as it allows to specify the clusters of countries with a similar level of innovativeness (e.g.: Poland on the MDS map is close to Slovakia, Hungary, Greece, and Romania, which means that unfortunately it is closer to the countries with a lower level of innovativeness, while the leaders, the Scandinavian countries, are naturally in the same cluster). The results of the conducted research confirmed earlier stated hypothesis that the degree of specialisation of an innovation index has a significant influence on the location/position of the EU Member States on a perceptual map. Moreover, observing the inclination angle of the vectors determined on the basis of the analysed innovation indices in relation to the axes connected with the dimensions (Dim 1 and Dim 2), it can be concluded that the *SII* index seems to be something of a resultant of measurements made with the *IOI* and *GII* indices. In turn, the latter two indices differ in terms of the direction of changes of the coordinate related to the second dimension, which may indicate that although they both measure innovativeness, their methodological differences will lead to noticeable differences in the assessment of the EU economies.

References

Beardsworth, A., Keil, T. (1992). The vegetarian option: Varieties, conversions, motives and careers. *Sociological Review*, 40. DOI: https://doi.org/10.1111/j.1467-954x.1992.tb00889.x.

Black, J. K. (1991). *Development in theory and practice: Bridging the gap.* Boulder, Colorodo: Westview.

Dutta, S., Lanvin, B., Wunsch-Vincent, S. (ed.), (2015). *The Global Innovation Index 2015. Effective Innovation Policies for Development*. Fontainebleau, Ithaca, and Geneva: Cornell University, INSEAD, the World Intellectual Property Organization (WIPO).

European Commission (2013). *Commission launches new innovation indicator*, Press Release, Brussels, 13 September 2013, http://europa.eu/rapid/press-release_IP-13-831_pl.htm.

European Commission (2015). *Innovation Union Scoreboard 2015*, Internal Market Industry, Entrepreneurship and SMEs, Belgium.

Giovannini, E., Uysal, A. (2006). *Statistics, Knowledge and Policy: What Do We Know About What People Know?* OECD Workshop on Business And Consumer Tendency Surveys. http://www.oecd.org/site/worldforum06/38445087.pdf.

Goldsmith, R.E., Foxall, G.R. (2003). The Measurement of Innovativeness, In Shavinina, L.V. (ed.), *The International Handbook on Innovaiton*. Prague: MAC Prague consulting Ltd. DOI: http://dx.doi.org/10.1016/b978-008044198-6/50022-x.

Hahn, G. J., Doganaksoy, N. (2008). *The Role of Statistics in Business and Industry*. Publisher: John Wiley & Sons.

Hirschberg, N., Jones, L., Haggerty, M. (1978). What's in a face: Individual diiferences in face perception? *Journal of Research in Personality*, 12(4). DOI: https://doi.org/10.1016/0092-6566(78)90074-0.

Hollanders, H., Van Cruysen, A. (2008) *Rethinking the European Innovation Scoreboard: A New Methodology for 2008-2010*, Genewa: Pro INNO Europe.

Kruskal, J. B. (1964). Nonmetric multidimensional scaling: A numerical method. *Psychometria*, 29. DOI: https://doi.org/10.1007/bf02289694.

Kruskal, J. B., Wish, M. (1978). *Multidimensional scaling.* California: Sage.

Majerová, I. (2015). Measurement of Innovative Performance of Selected Economies of the European Union and Switzerland. *International Journal of Information and Education Technology*, 5(3). DOI: https://doi.org/10.7763/IJIET.2015.V5.506.

Takane, Y., Young, F., & de Leeuw, J. (1976). Non-metric individual differences multidimensional scaling: an alternating least squares method with optimal scaling features. *Psychometrika*, 42. DOI: https://doi.org/10.1007/bf02293745 .

Wish, M., Deutsch, M., Biener, L. (1970). Differences in conceptual structures of nations: an exploratory study. *Journal of Personality & Social Psychology*, 16(3). DOI: https://doi.org/10.1037/h0030058.

Vertesy, D., Deiss, R. (2016). The Innovation Output Indicator 2016. Methodology Update; EUR 27880 EN. DOI: https://doi.org/10.2788/261409.

Young, F. W., and Hamer, R. M. (1987). *Multidimensional Scaling: History, Theory and Application*. New Jersey: Lawrence Eribaum Associates.

Zaborski, A., Pełka, M. (2013). Geometrical presentation of preferences by using profit analysis and R program. *Folia Oeconomia*. *Acta Universitatis Lodziensis*, 185.