INNOVATIVE ACTIVITY OF THE POLISH MANUFACTURING ENTERPRISES - STATISTICAL ANALYSIS

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ABSTRACT

Today's global economy is often described as one in transition to a knowledge-based economy. Knowledge management efforts typically focus on organizational objectives such as innovation, integration and continuous improvement of organizations. Increasing innovation activity is a prerequisite of socio-economic development and thus the growth of social welfare. This approach can yield impressive benefits to individuals and enterprises.

Innovation activity is a multidimensional, difficult to measure phenomenon. In this study, based on the Polish Classification of Activities, an attempt was made to measure innovation activity of manufacturing sectors (section C) on the two-digit level of aggregation. A synthetic measure of innovation activity – the innovation index which is a function of many variables – was applied in the study.

The objective of the presented study is to determine the innovation index and define a synthetic position of individual manufacturing sectors in terms of innovation activity on the basis of this index. The index, which is a measure of complete innovation of a given sector, was calculated by means of Principal Components Analysis and SPSS program.

In the study the statistical data on innovation activity of enterprises in manufacturing industry in Poland in the years 2007-2009 have been used.

Key words: knowledge economy, synthetic innovation measures, two-level models

INTRODUCTION

Innovation activity is an important issue in terms of an increase in competitiveness of enterprises, industries and sectors of the national economy. The issue of innovation is the key element in considerations related to the development of the EU member states. The lack of success in implementing the Lisbon Strategy aimed at making the European Union the most competitive world's region contributed to the emergence of a new EU development programme. In March 2010, the Europe 2020 Report – the UE strategy for smart, sustainable and inclusive growth – was published. This document delineates the new, long-term plan of socio-economic development of the EU that replaced the Lisbon Strategy; the knowledge and innovation based growth were recognised as one of the most important priorities [Innovation activities of enterprises in the years 2006-2009, Central Statistical Office of Poland, Warsaw-Szczecin 2010].

Innovation of enterprises forms the foundation essential to achieve the objectives of that strategy and is the key to create the competitive advantage, which is a solid base for sustainable growth.

Innovative processes have become the subject of intensive research and academic interest throughout the world. The need to conduct research into various aspects of innovation of enterprises also arises in Poland. Such studies ought to thoroughly diagnose the current situation in this respect and point to the development of relevant instruments of economic policy.

Improvement of industrial innovation is necessary in Poland in order to sustain and gradually increase the standard of living and to meet the challenges connected with international competition, environmental protection and an increased pace of world technological progress. The assessment of innovation of particular sectors of manufacturing industry and their classification according to their innovation ranking status allow to determine the development prospects of particular sectors.

Innovation is a multidimensional phenomenon which is difficult to measure. Due to low efficiency of singular innovation indicators, the synthetic indicator of innovation activity – the innovation index which is a function of many variables – was used in the study.

The aim of the presented study is to determine the innovation index and to define the significance of particular sectors in manufacturing industry using innovation ranking on the basis of innovation index.

The index, which is the measure of total innovativeness of a given sector, was calculated by the means of the Principal Components Analysis (PCA) using the SPSS software.
The study made use of the most recent statistical data contained in the abbreviated study of innovation activities of enterprises in the manufacturing industry carried out by the Central Statistical Office in Poland in the years 2007-2009. The study encompasses enterprises with more than 9 employees.

Principal Components Analysis (PCA) in construction of innovation index

The innovation index allows comparison of multidimensional objects which are described by a large number of variables. It is a function of all variable data which gives easy interpretation and possibility to compare different intensities and levels of development of the analysed phenomenon. All variables should be presented in the form of stimulants, which means that the higher the value of the variable, the better the innovative activity.

The innovation index may be interpreted as a complete measure of innovation activity in industrial sectors [Gomułka, 2006, p.296].
In many cases all variables describing innovativeness are attributed the same weight. In other situations they are usually arbitrarily estimated by experts. In the paper, the weights are calculated by using the Principal Components Analysis.
The Principal Components Analysis consists in orthogonal transformation of n-element set of primary variables (describing n-objects) into a new set of independent variables called the principal components. Each of the principal component is a linear function of standardized variables of primary forms (Malarska 2005, p. 214):

$$F_j = a_{j1}Z_1 + a_{j2}Z_2 + ... + a_{jn}Z_{n,}, \quad (1)$$

j=1,2,…,n
The model of Principal Components Analysis in the matrix record has the form of:

$$F = A^T Z \quad (2)$$

where:
$A = [a_{ji}]_{nxm}$ - the searched matrix of orthogonal transformation of the variables Z_j into F_j (j=1,2,…,n);
F_j - the principal element.
It results from the formula (1):

Z=AF (3)

In the model of the Principal Components Analysis, factor loadings a_{ji} (coefficients of matrix A), also called component weights, define the strength of correlation of variable Z_j with factors F_j (j = 1,2, …, n), by which the loads are placed.

Determining the principal components is an effect of multidimensional rotation of variables space which maximizes key variances of dimensions. It creates new space where the first dimension called the principal element represents the axis in primary space along which the data have the biggest variance. The second principal element represents the second row of data variances after excluding the variance translated by the first element. Then the principal elements are determined, so that the following variances (V) being a measure of their informative resources concerning the researched phenomenon, were smaller and smaller:

$$V(F_1) > V(F_2) > \ldots > V(F_n) \quad (4)$$

At the same time, the sum of variances of all primary variables equals the sum of principal elements variance, which means that the transformation of input variables into the principal elements does not lead to the loss of information about the researched phenomenon:

$$\sum_{j=1}^{n} V(F_j) = \sum_{j=1}^{n} V(Z_j) = n \quad (5)$$

As a rule, we can determine as many principal elements as original variables are. However, only a few of the first components contain the prevailing majority of information about the researched phenomenon (they explain most of variances in the set of data) and thus have an interpretative meaning. Such a situation permits a reduction of variables and little loss of primary information. The principal components are regarded as representations of strength affecting the researched phenomenon. The decision concerning the number of principal components (factors) that will be finally used in the analysis is a decision of subjective character, however, in practice some techniques (criteria) facilitating such a decision are used. They are the following (Panek 2009. pp.181-182):

- criterion of the proportion of explained variance,
- Kaiser's eigenvalue criterion,
- scree test criterion,
- criterion for significance of principal elements.

To obtain easy to interpret principal components, it is necessary to rotate the axis – factors of the reference system with the values of factor loadings. Popular methods of rotation are: quartimax, varimax and equamax. The rotation of the axis causes each variable to be matched with the smallest possible number of factors. The variables strongly connected with a given component give a clear, easy to interpret picture of homogenous group connections.
In the case of data concerning innovation, the assumption was accepted that the first principal element represents the phenomenon of general innovation activity. The assumption is methodologically justified as all the variables

included in the research are indicators of innovation.

Innovation index in sectors of the manufacturing industry

The innovation analysis was carried out in 24 sectors (two-digit level of aggregation according to the Polish Classification of Activity 2007) of the manufacturing industry (section C). On the basis of data of innovation activities of enterprises in the manufacturing industry carried out by the Central Statistical Office of Poland, a set of potential diagnostic indicators of innovation for the sectors of the manufacturing industry in Poland in the years of 2007-2009 was created (Table 1).

Table 1. The list of variables used in the study

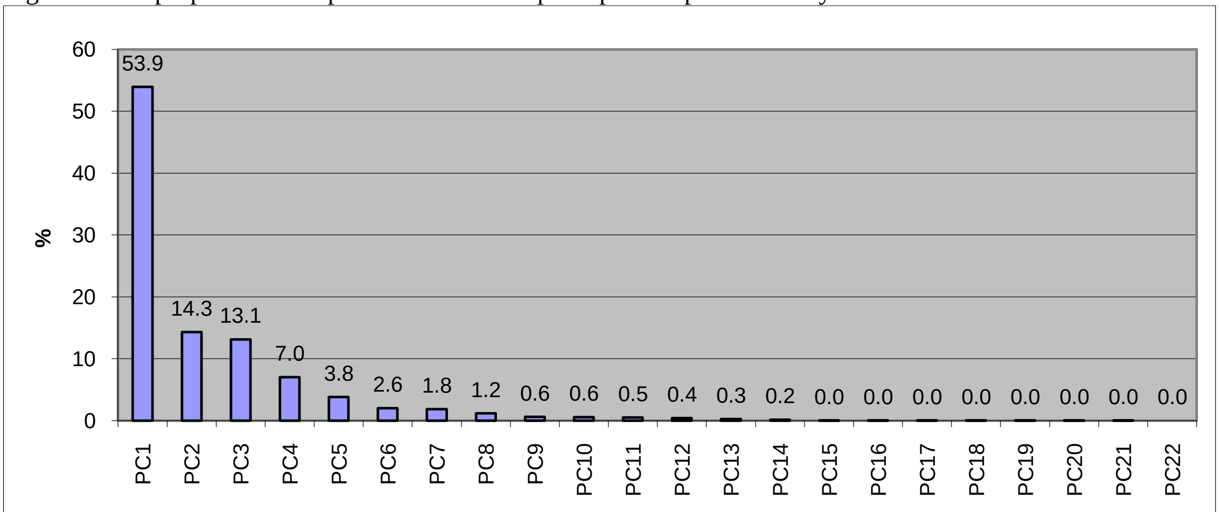
Symbols	***Name of the variable***
X1	Innovative enterprises as a % of total number of enterprises
X2	Enterprises that introduced new or significantly improved products as a % of total number of enterprises
X3	Enterprises that introduced new or significantly improved products to the market as a % of total number of enterprises
X4	Enterprises that introduced new or significantly improved processes as a % of total number of enterprises
X5	Enterprises that introduced new or significantly improved processes, including methods of product manufacturing, as a % of total number of enterprises
X6	Enterprises that introduced new or significantly improved processes, including methods in the field of logistics and/or methods of product delivery and distribution, as a % of total number of enterprises
X7	Enterprises that introduced new or significantly improved processes, including methods facilitating these processes, as a % of total number of enterprises
X8	Profits from the sales of new and significantly improved products as a % of total sales value
X9	Profits from the sales of new products for the market as a % of total sales value
X10	Profits from the sales of new products for the enterprise as a % of total sales value
X111	Expenditure on innovation activities per enterprise (in mln PLN)
X112	Expenditure on R&D as a % of total expenditure on innovation activities
X113	Expenditure on purchasing knowledge from external sources as a % of total expenditure on innovation activities
X114	Expenditure on purchasing software as a % of total expenditure on innovation activities
X115	Expenditure on investment in buildings, structures and land as a % of total expenditure on innovation activities
X116	Expenditure on investment in machinery and technical equipment as a % of total expenditure on innovation activities
X117	Expenditure on investment in imported machinery and technical equipment as a % of total expenditure on innovation activities
X118	Expenditure on investment in human resources training related to innovation activity as a % of total expenditure on innovation activities
X119	Expenditure on investment in marketing of the innovative products as a % of total expenditure on innovation activities
X20	Enterprises cooperating in the area of innovation as a % of total number of enterprises
X21	Enterprises cooperating in the area of innovation as a % of total number of innovative enterprises
X22	Enterprises with cooperation agreements within the framework of cluster initiative focused on innovation activity as a % of total number of innovative enterprises
X23	Enterprises with cooperation agreements within the framework of cluster initiative focused on innovation activity as a % of total number of enterprises that took up cooperation in the area of innovation activities
X24	Enterprises introducing organizational and/or marketing innovations as a % of total number of enterprises
X25	Enterprises introducing organizational innovations as a % of total number of enterprises
X26	Enterprises introducing marketing innovations as a % of total number of enterprises
X127	The number of automated production lines per enterprise

Source: The authors' own elaboration

The initial analysis showed that variables X114, X115, X116, X118 and X23 are negatively correlated with most of the other variables describing the innovation index. Additionally, the analysis of reliability of the constructed indicator was carried out and it resulted in Cronbach's alpha coefficient of 0.839. The result is quite good, however, after deleting certain scale components (components of the synthetic indicator), there is a noticeable improvement in the reliability of the scale. It reinforced the need to remove indicators of innovation X114, X115, X116, X118 and X23 from further analysis. Variables X114, X115, X116 and X118 are structural indicators that measure the percentage of certain type of expenditure in total expenditure on innovation activity. Thus, it can be concluded that expenditure on purchasing software (variable X114), expenditure on buildings, structures and land (X115), expenditure on machinery and technical equipment (X116) as well as expenditure on human resources training related to innovation activity (X118) are less relevant from the perspective of innovation. In the expenditure on innovation activity, expenditure on R&D (X112) and on marketing of new or significantly improved products (X119) are important.

Both Bartlett's test and KMO indicate that factor analysis could be applied. Originally, by means of the principal components method, 22 components, explaining in smaller and smaller variance, were extracted. Figure 1 presents the variance distribution explained by each of the newly created principal components (PC).

Figure 1. The proportion of explained variance in principal components analysis



Source: The authors' own elaboration

The first and second component account for 68% of total variance, PC1 explains as much as 54%. Further components explain variance to a lesser degree, the proportion of variance explained by 14 components (PC9-PC22) does not exceed 1%.

While using the principal components method, the problem connected with making decision as to the number of principal components (factors) that ultimately should be used in the analysis always arises. In the study presented in this paper, the first four components have the value greater than one, which means that Kaiser's criterion of eigenvalue that accompanies these features points to extraction of four principal components. The choice of four components is also confirmed by the scree test. Ultimately, taking also into consideration the proportion of explained variance (communality), four principal components remained. From the perspective of statistical assessment, this model is the best and explains 88.5% variance of the phenomenon.

Interpretation of the received principal components is carried out on the basis of the rotation values of their coefficients that simultaneously form the coefficients for linear correlation between the initial variables and principal components. In the study, quartimax, varimax and equamax rotation methods were used. The best results, which enable and facilitate formal and substantive assessment of innovativeness, were obtained by the quartimax method.

Table 2. The rotated component matrix.

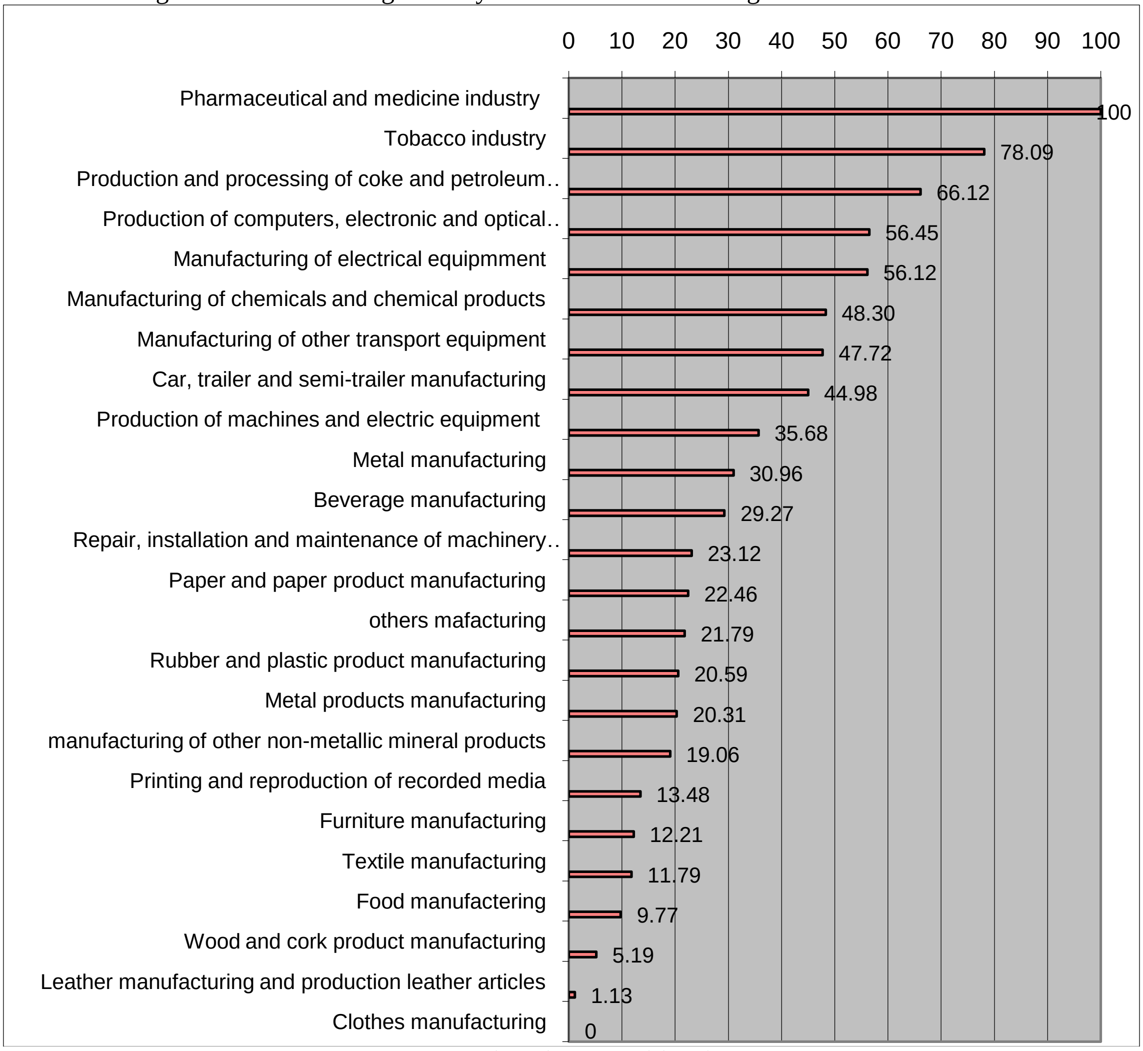
	Component			
	1	2	3	4
X4	**.985**	-.063	.047	-.005
X7	**.977**	-.046	.034	-.009
X24	**.975**	.015	-.011	.106
X5	**.968**	-.126	-.079	.053
X1	**.962**	.109	.189	.086
X25	**.956**	-.069	-.006	.130
X6	**.945**	-.012	-.177	-.094
X26	**.901**	.299	-.093	-.080
X2	**.864**	.304	.266	.179
X3	**.854**	.020	.338	.234
X127	**.841**	-.087	.081	-.403

X20	**.782**	.230	.546	.087
X113	.376	**.812**	.028	.032
X112	.130	**.763**	.037	.322
X119	.471	**.740**	-.086	-.319
X117	.311	**-.729**	.203	.058
X111	.247	-.313	**.838**	-.159
X10	.444	-.320	**.737**	.133
X21	.491	.153	**.699**	.258
X22	.146	.297	**.569**	.489
X9	.090	.085	-.054	**.955**
X8	.295	-.089	.324	**.842**

Factor extraction method – principal components.
Rotation method - Quartimax with Kaiser normalization.
Rotation converged in 5 iterations

Figure 2. presents sectors of manufacturing industry classified according to the level of innovation measured by the calculated index. The results were categorized, so that the sector with the highest measured level of innovation achieved the score of 100 and all the others achieved proportionally smaller results.

Figure 2. Manufacturing industry sectors ranked according to their innovativeness



Source: The authors' own elaboration

The most innovative is sector 21 - Manufacturing of basic pharmaceutical substances, medicine and other pharmaceutical products. Most values of innovation indicators for this sector were significantly higher than the mean for the sectors. The value was particularly high in the case of enterprises that introduced new products (X2) and cooperated in terms of innovation activity with other entities (X20). This sector is also distinguished in a positive way among others not only by its high level of expenditure on innovative activities (X111) but also by the structure of this expenditure. A relatively high proportion of expenditure on R&D, expenditure on purchasing knowledge from external sources (X113) and particularly high, i.e. 25%, proportion of expenditure on marketing of new or significantly improved products (X119) can be observed in the expenditure structure.

Innovation of tobacco manufacturing, reached the second position is, by 22 points lower than the first sector. Among all the sectors, tobacco industry was characterised by the highest proportion of innovative enterprises and enterprises that applied new and improved processes in their activity. Expenditure on machinery and equipment also ranked high in the expenditure structure on innovation activities.

Sector 19 – production and processing of coke and petroleum refining products – was the third-ranking sector. Enterprises in this sector incurred the biggest expenditure on innovation activities per enterprise. This sector stood out not only in terms of the level of expenditure on innovation activity but also in terms of the results of innovation activity. The proportion of profits from the sales of innovative products as a total % value of sales was the highest one in comparison with other sectors.

The high ranking position of the top sectors is most likely the result of intense market competition, transfer of technology caused by the inflow of foreign capital as well as the necessity to adjust production methods to the EU rules and regulations.

The calculated index points to a high diversity of innovation activity of enterprises in the manufacturing industry. As many as 19 out of 24 sectors of manufacturing industry are characterised by innovativeness below 50 points.

The last three sectors in the ranking – wood and cork product manufacturing, excluding furniture manufacturing, production of articles made of straw and weaving materials, leather manufacturing and production of leather goods as well as clothes manufacturing are the "low-technology" sectors, labour intensive, in which manual labour cannot be easily replaced by machinery. Thus, innovations are implemented less extensively than in the case of the top ranking sectors. Foreign capital was also less interested in investing in these production activities.

CONCLUSIONS

Innovation in sectors of manufacturing industry was assessed by means of the synthetic innovation indicator (index). The applied method of principal components verifies which of the variables are highly correlated and can create an index as well as gives possibility to calculate the weight for particular variable.

Innovation index shows that the sector of manufacturing of basic pharmaceutical substances, medicine and other pharmaceutical products was the leader of innovation in the years 2007-2009. This sector, according to OECD classification, is classified as one of "high-technology" industries.

The second position in the innovation ranking is occupied by tobacco manufacturing ("low technology"), and the third one by production and processing of coke and petroleum refining products (medium-low technology). While assessing innovativeness of tobacco industry, it is worth to draw attention to a small number of enterprises functioning in this sector – there are only 11 of them. The size of this sector should be taken into account in drawing conclusions since there is a larger probability of atypical results in a small sample.

The last positions in the innovation ranking were occupied by "low technology" sectors.

Manufacturing industry innovation index confirms the expectations concerning low and medium innovativeness, offers, however, some unexpected results for the enterprises at the top of the ranking. The high positions in the ranking were occupied by sectors of manufacturing industry classified as "low and medium-low technology".

Innovation index is a valuable instrument to assess in a synthetic way innovativeness of manufacturing industry in Poland.

The proposed analysis could be used as guidelines concerning the future policy of support for innovation activity of enterprises in manufacturing industry.

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