Multivariate statistical analysis of innovativeness of manufacturing companies in Poland - selected aspects

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ABSTRACT

Innovativeness of industrial enterprises is an important factor of firms and the whole economic development. Introduction of new improved products, processes and methods of production are factors which increase productivity. In order to maintain their market position companies need to be constantly developed and innovative.

Investigations in this area seem to be connected with identification, measuring and scale determining of innovativeness of economy at different statistical aggregation levels. So, there is a need to present methods or measures which are enable to asses a degree of innovativeness.

The aim of the paper is to construct statistical classes of innovativeness of manufacturing activities in Poland in the years 2009-2011 using linear object grouping and cluster analysis. In the empirical verification data based on NACE-Revision Classification gathered by Central Statistical Office are used. They come from the study of innovation activities of enterprises conducted in the period 2009-2012.

The results presented in the paper could be useful for economic policy of manufacturing innovativeness.

Key words:

diagnostic variables; linear ordering procedure; cluster analysis; manufacturing industries; innovativeness; rank of the manufacturing classes in Poland

***Thematic area*:** statistical methods

1. INTRODUCTION

In the era of global competition and the knowledge-based economy, an increase in the innovativeness of the national economy is a prerequisite for the socio-economic development and, therefore, increased social welfare. It should be noted, however, that there is no innovative economy without innovative companies. Hence, innovation at the macro level is the result of the aggregation of innovation at lower levels.

Innovativeness is a multidimensional phenomenon and it is not easily measurable. There are many definitions of innovation and innovativeness pointing to different aspects of this issue. Most of these definitions lead to the conclusion that innovation is something new, which in its essence increases the value of the object. Therefore, it is necessary to develop an approach that will enable multi-dimensional perception of innovations, in terms of determinants, as well as results obtained.

The aim of the presented study is a statistical evaluation of innovativeness of divisions of the manufacturing sector in the years 2009-2011, carried out on the basis of statistical methods of linear ordering. Accepting the view of Z. J. Acs and D.B. Audretsch on lower efficiency of individual measures of innovativeness, this study made an attempt to conduct a synthetic evaluation of innovativeness of manufacturing companies.

The study used statistics provided by the partial study of innovative activity of enterprises in the years 2009-2011 conducted by the Central Statistical Office of Poland (CSO) in 2012. This study encompasses manufacturing companies and service companies and was included in the Statistical Research Programme of Official Statistics (Program Badań Statystycznych Statystyki Publicznej) in the areas 1.43.02 – *Innovation in the manufacturing sector* (PNT-02) and 1.43.13 – *Innovation in the service sector* (PNT-02/u). In contrast to the previous period of 2008-2010, the study was the partial version of the *Community Innovation Survey* (CIS) carried every two years by the European Community which aims at ensuring the continuity of analysis of innovativeness and at providing data for the needs of domestic recipients. The research encompassed companies which employed more than 9 people. The full study covered only manufacturing enterprises employing 50 or more people, whereas the representative study covered manufacturing companies that employed 10-49 people, as well as entities from the service sector of both classes in terms of size.

This study, taking into consideration the Polish Classification of Activity (PCA), attempted to measure innovativeness of manufacturing companies (section C) at the two-digit level of aggregation, i.e. at the level of divisions of this section. This level of aggregation was considered sufficiently detailed and relevant to the assessment of innovative activities of manufacturing companies.

Innovativeness of manufacturing enterprises is an important factor determining the development of companies and although the methodology of research on innovativeness of companies is still being developed and refined[1], innovation indicators can be already considered a valuable source of information in assessment of their innovativeness.

This paper discusses the key indicators that characterise innovativeness of manufacturing companies, presents selected issues concerning methods of linear ordering of objects, as well as the results of the preliminary analysis of data and the results of the multivariate statistical analysis evaluating innovativeness of manufacturing companies in Poland in the years 2009-2011.

2. INDICATORS OF INNOVATIVENESS OF MANUFACTURING COMPANIES

Based on the results of the PNT-02 study *Innovation in the manufacturing sector* conducted by the CSO in the framework of the CIS programme, a set of potential diagnostic indicators of innovativeness of companies in the food industry in Poland in the years 2009–2011 was created and their values constituted a starting point for the analysis of innovativeness of manufacturing companies. These include:

1) the share of innovatively active enterprises in the total number of enterprises in the given area of activity,

[1] Work on the statistical studies concerning innovation was initiated by the European Commission at the beginning of 1990s. The significance of statistical studies on innovation in the EU can be seen in the statement given at the conference entitiled *Innovation measurement and policies* in Luxembourg in 1996: *"Statistical research of innovation and other methods to measure innovation should be developed in a way that would allow them to achieve in the future the status similar to that of national accounts"* , as well as legislative acts constituting the current legal basis for statistical research on innovation in the EU and EFTA member states [CSO 2006, p. 17].

2) the share of innovative enterprises in the total number of enterprises in the given area of activity,
3) the share of enterprises that have introduced new or significantly improved products in the total number of enterprises in the given area of activity,
4) the share of enterprises that have introduced new or significantly improved processes in the total number of enterprises in the given area of activity,
5) the share of enterprises that have introduced new or significantly improved products and processes in the total number of enterprises in the given area of activity,
6) the share of enterprises that have introduced organisational innovations in the total number of enterprises in the given area of activity,
7) the share of enterprises that have introduced marketing innovations in the total number of enterprises in the given area of activity,
8) the share of revenues from the sale of new or significantly improved products in the total sales,
9) the share of enterprises which in 2009-2011 received state aid for innovative activity in the number of innovatively active enterprises,
10) the share of manufacturing enterprises which have cooperation agreements concerning innovation activities with other entities in the number of innovatively active enterprises,
11) the share of enterprises that have cooperated in a cluster initiative in the field of innovation activity in the total number of enterprises that cooperate in the field of innovation,
12) the sum of automated means of controlling production processes installed per company,
13) the share of equity in expenditures on innovation activity in the area of product and process innovations,
14) internal expenditure on R&D in million PLN.

The objects of the study are industrial companies that operate in the divisions of the Manufacturing section.

3. LINEAR ORDERING PROCEDURE

Methods of linear ordering of objects described by a set of many diagnostic features are included in methods of the multivariate statistical (MSA). Their idea is to organise elements of the analysed set of objects according to the values of the selected diagnostic features (or indicators) based on the defined primary criterion of their evaluation [Grabiński et al. 1989, pp. 53-54]. This ordering is usually connected with the construction of a synthetic index for the objects which is the measure of the studied phenomenon resulting from the conducted analyses. Universality of methods of linear ordering means that they are often used for various socioeconomic comparisons.

The issue of linear ordering of objects can be viewed in static or dynamic terms.

General scheme of linear ordering of objects in static terms can be described by six successive stages[2]:

1) Formulation of the objective of the analysis and preliminary research hypotheses.
2) Determination of the scope (objects, indicators) and duration of the study.
3) Construction of the database containing the values of acceptable diagnostic indicators.
4) The preliminary analysis of data:
   - The descriptive analysis of diagnostic indicators (measures of location, range, variance).
   - The correlation analysis, reduction and selection of diagnostic indicators.
   - Determination of the nature of diagnostic indicators and their possible stimulation.
   - Determination of weights for diagnostic indicators.
5) Linear ordering of objects:
   - Normalisation of diagnostic indicators.
   - The choice of the aggregation formula of diagnostic indicators (the model-based method, the non model-based method, the method of orthogonal projection of objects onto the line).

- Evaluation of the quality of the results obtained and the selection of the optimal solution.

6) Interpretation of the results of linear ordering of objects.

The first three stages of the linear ordering scheme of objects in statistical terms do not require any comment as they are typical of different types of analyses. The main objective of the fourth stage, the preliminary analysis of data, is the assessment of the properties of the diagnostic indicators and their choice for the analysis. At this stage, the transition from a set of acceptable indicators, determined on the basis of substantive and procedural grounds, to the set of diagnostic indicators occurs. This is an important stage as too many diagnostic variables, non-essential or excessively correlated, can make it difficult to obtain the proper - the best in terms of quality - result of linear ordering of objects (divisions of enterprises).

The selection of diagnostic features should be based on the following information criteria [Ostasiewicz 1999, p. 110]: universality – features should be characterised by a widely recognised weight and relevance for the subject of the analysis; variation - features should not be similar to each other in terms of information about the objects studied, yet they should be characterised by a great ability to differentiate objects (high variation); significance – indicators for which the objects studied not easily achieve high (significant) values; correlation – the selected indicators should be poorly correlated with each other, at the same time being strongly correlated with indicators excluded from the analysis by means of reduction.

To assess the variation of potential diagnostic indicators, the analysis may make use of the relative measure of their dispersion, i.e. the classical coefficient of variation (v_j). The indicators for which $v_j < 0{,}1$ are eliminated out of the set of potential diagnostic indicators.

Another measure of variation is the coefficient of the relative amplitude of fluctuations $A(X_j)$ for the given index. If X_j is a stimulant, then $A(X_j)$ shows how many times the highest value of the given index for the first ranked object exceeds the

[2] The author's own compilation based on [Grabiński et al. 1989, pp. 87-89] and [Kolenda 2006, pp. 139-

lowest value of this index for the last ranked object (for a destimulant, the interpretation is reversed) [Kukuła 2000, pp. 47-52]:

$$A\left(X_j\right)=\frac{\max_i x_{ij}}{\min_i x_{ij}},\ \left(i=1,\dots,n;\ j=1,\dots,m\right), \qquad (1)$$

wherein $\min_i x_{ij} \neq 0$. The adoption of the additional condition that the coefficient

$A\left(X_j\right) \geq c$,

where $c=1{,}2$ allows the elimination of low amplitude fluctuation variables.

The next step of the analysis is the determination of the character of the diagnostic indicators and their possible stimulation which consists in the conversion of values of destimulants and nominants into stimulants. This transformation is required for non model-based methods of linear ordering of objects, it aims at unifying the character (preferences) of the indicators employed to construct a synthetic index (measure) and precedes the stage of their normalisation.

The issue of weighting variables, i.e. assigning them specific weights in order to differentiate the significance of particular diagnostic features in the analysis is a controversial issue. In general, the same significance of each variable is assumed based on the argument about the lack of non-trivial ways to weigh them with the use of additional information, then:

$$\alpha_j = 1/m,\ \left(j=1,\dots,m\right). \qquad (2)$$

On the other hand, literature presents methods for determining weights based on the information contained in the statistical data used for the analysis, e.g. based on variation (5), correlated features (6) or elements of the first principal component, i.e. the factor analysis of the correlation matrix of diagnostic features [Grabiński et al. 1989, pp. 25-27]:

$$\alpha_j = \frac{v_j}{\sum_{j=1}^{m} v_j},\ \left(j=1,\dots,m\right), \qquad (3)$$

140].

v_j – the variation coefficient of X_j index prior to its normalisation[3],

$$\alpha_j = \frac{r_{jp}}{\sum_{j=1}^{m}\sum_{p=1}^{m} r_{jp}} \ , \ (j, p = 1,...,m), \tag{4}$$

r_{jp} – the elements of the correlation matrix $R_{m x m}$ prior to normalisation of indices.

It is known that using the formulas (5) and (6), higher weights will be assigned to the indices with a relatively high degree of variation or high correlation with the other diagnostic indicators. It should be also noted that the potential weight calculation is carried out on the basis of the original values of diagnostic variables and the procedure of their weighing is applied after the normalisation of variables, at the stage of value aggregation for diagnostic features.

The fifth stage of the analysis is the stage of actual linear ordering of objects, related to the selection of formula for data aggregation, and it is preceded by normalisation and weighing of diagnostic indicators. Procedures for normalisation and aggregation of variables are the most extensive part of literature concerning methods of linear ordering of objects. The variety of known methods makes this most important stage of the analysis the most difficult.

The main objective of normalisation of diagnostic features adopted for the analysis is obtaining unitless values of variables and standardisation of their order of magnitude. The basic requirement for normalisation procedures is for the transformation to maintain correlation between features and for basic indicators to maintain the shape of their distributions (skewness, kurtosis). These properties are satisfied by the linear transformation of variable $X_j = (x_{1j}, x_{2j},..., x_{nj})^T$ into $Z_j = (z_{1j}, z_{2j},..., z_{nj})^T$ in the form of [Zeliaś 2000, p. 792]:

[3] Weights determined on the basis of coefficients of variation of features from the perspective of their properties are not appropriate for the analysis since they do not take into consideration relationships between variables and may lead to marginalisation of certain variables chosen at the earlier stage of selection and reduction of variables.

$$z_{ij} = \frac{x_{ij} - a_j}{b_j} \ , \ (j = 1,...,m), \tag{5}$$

$$z_{ij} = \frac{a_j - x_{ij}}{b_j} \ , \ (j = 1,...,m), \tag{6}$$

respectively for the stimulants (7) and the destimulants (8) wherein, if: a_j is a measure of the location of the given feature, e.g.: the arithmetic mean $a_j = \bar{x}_j$, and b_j is a measure of its variation, e.g.: the standard deviation $(b_j = s_j)$, it is the standardisation transformation; if b_j is a measure of variation – range $b_j = \max_i x_{ij} - \min_i x_{ij}$, it is the unitarisation transformation; when $a_j = 0$ $(b_j > 0)$, it is the quotient transformation.

Literature in this field provides many normalisation transformations since it is acceptable to substitute a_j and b_j parameters with other characteristics of the studied variables[4], respectively: the minimal value, the maximum value, the median value, as well as the median absolute deviation, the sum of values x_{ij} or the sum of squared values x_{ij}. Only the theoretical analysis of properties of these different normalisation methods [Kukuła 2000, pp. 77-100] enables the assessment of their usefulness, their selection and application for linear ordering of objects of transformations characterised by the best properties.

It appears that only the method of zero unitarisation with the parameters of, respectively, $a_j = \min_i x_{ij}$ and $b_j = \max_i x_{ij} - \min_i x_{ij}$ for stimulants and $a_j = \max_i x_{ij}$ and $b_j = \max_i x_{ij} - \min_i x_{ij}$ for destimulants, resulting in normalised values of diagnostic indicators in the rage of $\langle 0;1 \rangle$, meets all the theoretical requirements of the normalisation formula and provides universal standardisation of all features. Next in the

[4] In terms of normalisation procedures: Grabiński et al. 1989, pp. 27-28 indicate 3 transformations most often used in practice; Domański et al. 1998, pp. 49-48 present 5 standardisation transformations and 10 quotient ones; Kukuła 2000, pp. 106-110 adopts a different division of normalisation methods and describes 10 normalisation transformations; Zeliaś 2002, pp. 792-794 presents 2 standardisation methods, 4 unitarisation methods and 6 quotient transformation ones; Walesiak 2006, pp. 16-22 analyses the total of 11 transformations; while Młodak 2006, pp. 39-42, respectively, 4 standardisation methods, 7 unitarisation methods and 8 quotient ones, including also the author's proposals using location statistics.

ranking are: the classical standardisation formula with the parameters $a_j = \bar{x}_j$ and $b_j = s_j$ and the quotient transformation with the parameters $a_j = 0$ and $b_j = \sum_{i=1}^{n} x_{ij}$. It is worth noting that these two last transformations – the standardisation and quotient ones – are most often used in practice.

The proper step at the stage of linear ordering of objects is the choice of the formula for aggregation of diagnostic variables. The most commonly used are two types of methods of linear ordering [Grabiński et al. 1989, pp, 31-32]: model-based methods involving the construction of a hypothetical model object which constitutes the point of reference for the conducted analysis (initiated by Hellwig) and non model-based methods involving the construction of a synthetic index. Literature presents also a third group of methods for linear ordering of objects – the orthogonal projection of objects onto the line. The synthetic index M of the μ_i values for $i-$th object $(i = 1,...,n)$ calculated on the basis of the normalised variables z_{ij} and weights α_j $(j = 1,...,m)$ assigned to variables $\alpha_j \in (0; m)$ for which in particular $\sum_{j=1}^{m} \alpha_j = 1$ can be expressed as the arithmetic, harmonic and geometric mean of diagnostic indicators. In comparative studies, the most commonly used formula is based on the mean value of normalised diagnostic indicators [Gatnar, Walesiak 2004, p. 355]:

$$\mu_i = \frac{1}{m} \sum_{j=1}^{m} \left(z_{ij} \alpha_j \right), \qquad (7)$$

which can be used when all variables (stimulants, destimulants, nominants) were originally measured on the interval or quotient scale; stimulation involved differential and quotient mapping; whereas normalisation was carried out by means of standardisation, unitarisation or zero unitarisation.

Relatively recently, only since 2006, literature has seen the need to assess the quality of results of rankings and to select the optimal solution in order to avoid drawing conclusions based on rankings constructed with the use of “randomly” selected incremental procedures. For this purpose, it is necessary to conduct several variants of the analysis of linear ordering of objects using the “best” incremental calculating procedures, taking into account their theoretical properties, and then to evaluate the quality of the results (of the ordering) obtained.

While evaluating the quality of the result of the ranking in statistical terms, e.g. according to various sorting methods, for the same set of objects with the use of the same normalised feature values, the method of directional variance of the synthetic variable M^* may be used, expressed in the formula [Kolenda 2006, pp. 137-140]:

$$s^2\left(M^*\right)=\frac{\sum_{i=1}^{n}\left(\mu_i^*-\overline{\mu}^*\right)^2}{n}\ ,\ \left(i=1,\dots,n\right), \tag{8}$$

where: $\overline{\mu}^*$ are the values of the synthetic variable M^*, $n-$ is the number of objects and $\overline{\mu}^*$ is the arithmetic mean of the synthetic variable M^* $\left(\overline{\mu}^*=0\right)$ μ_i^* determined as follows:

$$\mu_i^*=\sum_{j=1}^{m}\left(z_{ij}w_j\right),\ \left(i=1,\dots,n\right), \tag{9}$$

$$\sum_{j=1}^{m}w_j^2=1,\ w_j>0, \tag{10}$$

wherein w_j are the weights that are the coordinates of the unit vector.

In order to use the method of directional variance in the assessment of the quality of ordering of the objects in the ranking, the result of object ordering obtained on the basis of the method of orthogonal projection of objects on the line or the appropriate, transformed result is needed. It appears that any other result of object ordering obtained on the basis of the value of, for example, the synthetic index M with any weights α_j summing to unity can be transformed into the result of ordering of objects of the value of measure M^* (orthogonal projection) with the weights w_j determined by the formula (13), satisfying the condition (14):

$$w_j=\frac{\alpha_j}{\sqrt{\sum_{j=1}^{m}\alpha_j^2}}, \tag{11}$$

$$\sum_{j=1}^{m} w_j^2 = \frac{\alpha_1^2 + \alpha_2^2 + ... + \alpha_m^2}{\sum_{i=1}^{m} \alpha_j^2} \Rightarrow \sum_{j=1}^{m} w_j^2 = 1. \tag{12}$$

Conversion of weights has no bearing on the result of ordering since all proportions between weights are maintained and the order of objects in the ranking does not change.

The idea of the method for the assessment of accuracy of object ordering result with the use of the directional variance can be explained as follows: [Kolenda 2006, pp. 137-140; Mikulec 2008, p. 35]:

- Due to the determination of the unit vector of the weights w_j (5.17), determining the slope of the line, this method comes down to the selection of the line of the orthogonal projection of objects for which the sum of distances of the orthogonal projections o_i' of all the objects o_i onto this line will be the smallest. This case helps to explain the majority of the variances shared between the features that describe the objects sorted.
- Along with the increased fit of this searched for line to the objects o_i, the sum of distances of projections o_i' of objects o_i from the beginning of the coordinate system (sum μ_i^*) will tend towards the sum of distances of all the studied objects o_i from the beginning of the coordinate system, which is the maximum distance of these objects and which is unambiguous characteristics of the given set of ordered objects.
- If, therefore, the sum of μ_i^* values, calculated on the basis of the normalised values of individual z_{ij} variables, tends towards a maximum, the average sum of squares $s^2(M^*)$, i.e. the directional variance of the synthetic variable expressed in the formula (10) under the conditions $\bar{\mu}^* = 0$, tends to a maximum and is an explicit criterion for choosing the best ordering of objects. The above-presented considerations remain valid also in the case of linear ordering of objects described by the m multi-dimensional set of diagnostic features $(m > 2)$.

The final step of the analysis is to determine the correlation of diagnostic indicators with the synthetic variable, interpretation of linear ordering of objects and their graphical representation.

4. PRELIMINARY ANALYSIS OF DATA – SELECTION OF DIAGNOSTIC INDICATORS

At the first stage of the preliminary analysis of data, based on the measures of descriptive statistics (location, range, variance), the assessment of the usefulness of potential diagnostic indicators was carried out. All the indicators were characterised by sufficient variation $v_j > 10\%$ and sufficient amplitude of fluctuations.

At the next stage of the preliminary analysis of data, the correlation of potential diagnostic indicators was assessed for the purpose of reduction and the final selection of the set of diagnostic features. Diagnostic indicators (j rows) for which the sum of the absolute values of correlation coefficients in the correlation matrix row R was the largest were removed. When adding up the coefficients in j row of correlation matrix R only the strongly correlated variables $(r_{j\bullet} > 0{,}5)$ were taken into account. Thus, diagnostic indicators the most strongly (in total) correlated with the other analysed indicators were removed from the analysis.

To sum up, as a result of the correlation analysis, the indicators numbered: 3, 4, 2, 6, 11, 5, 7 and 14 were removed from the further analysis. Finally, for the construction of rankings of innovativeness of manufacturing enterprises, the set of 6 diagnostic indicators presented in Table 1, which were treated as stimulants of the evaluation of innovativeness of enterprises, was used.

Table 1. Diagnostic indicators of innovativeness of manufacturing companies

Item	Symbol [a]	Preferences [b]	SPECIFICATION
1	X8	S	The share of enterprises that have introduced marketing innovations in the total number of enterprises in the given area of activity
2	X9	S	The share of revenues from the sale of new or significantly improved products in the total sales
3	X10	S	The share of enterprises which have received state aid for

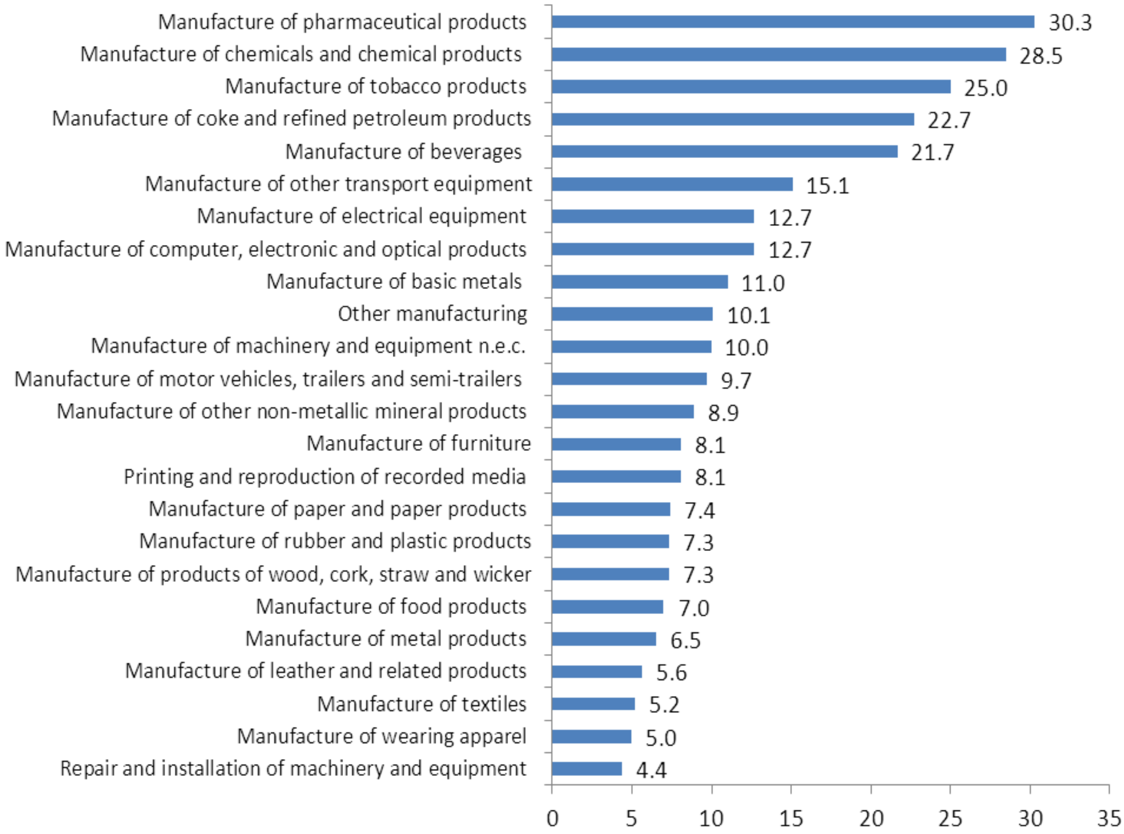
			innovative activity in the number of innovatively active enterprises
4	X12	S	The share of enterprises that have cooperated in a cluster initiative in the field of innovation activity in the total number of enterprises that cooperate in the field of innovation
5	X13	S	The sum of automated means of controlling production processes installed per company
6	X15	S	Internal expenditure on R&D in million PLN

a The symbol of indicators corresponds to their numbering in point 2. *b* S – stimulant.

Source: own elaboration

In terms of the first of the above-presented diagnostic indicators, i.e. the share of enterprises that have introduced marketing innovations in the total number of enterprises (X8), in the period of 2009-2011 the following divisions stood out – *Manufacture of pharmaceutical products* (30.3%), *Manufacture of chemicals and chemical products* (28.5%), *Manufacture of tobacco products* (25%), *Manufacture and processing of coke and refined petroleum products* (22.7%) and *Manufacture of beverages* (21.7%). In the remaining divisions, the percentage of companies introducing marketing innovations was significantly lower and in the case of the division of *Repair, maintenance and installation of machinery and equipment*, this share amounted to only 4.4% (see: Fig. 1).

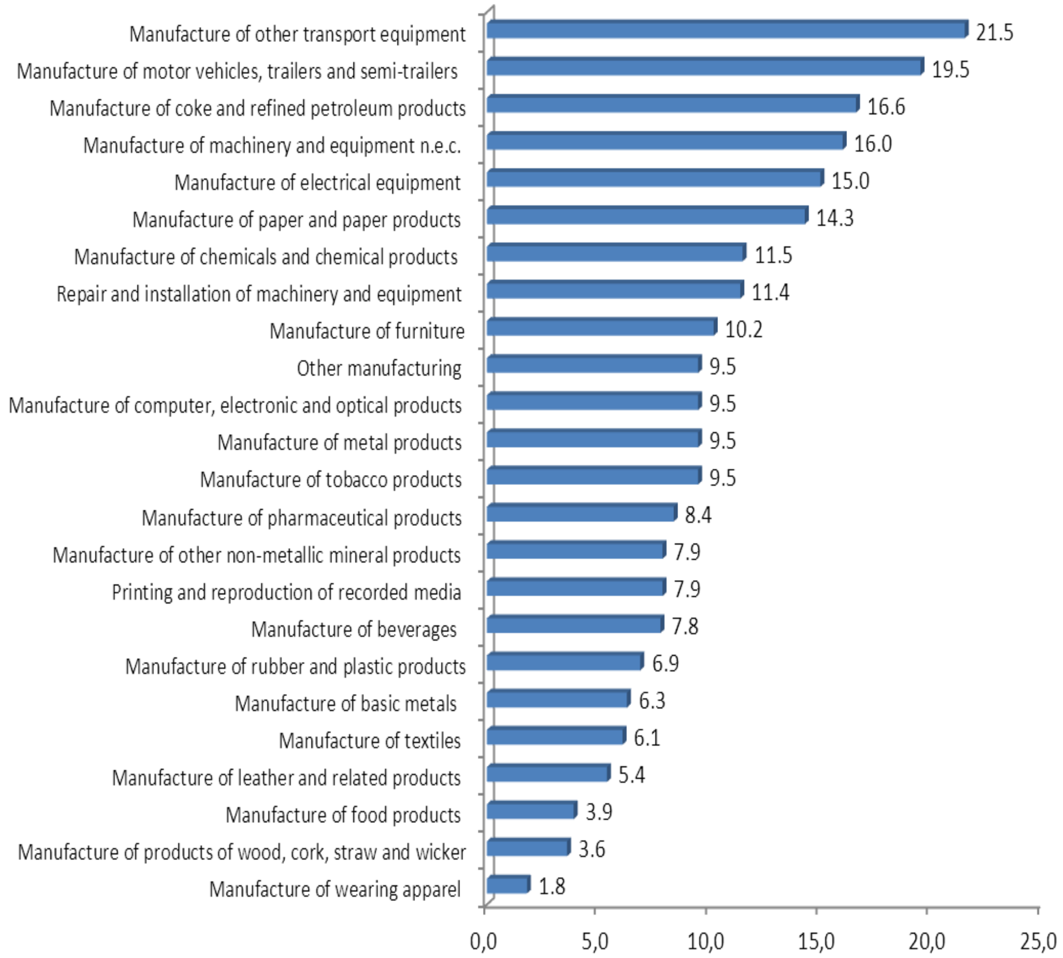
Figure 1. Companies that in the years 2009-2011 introduced marketing innovations by the divisions of the Polish Classification of Activity



Source: own elaboration

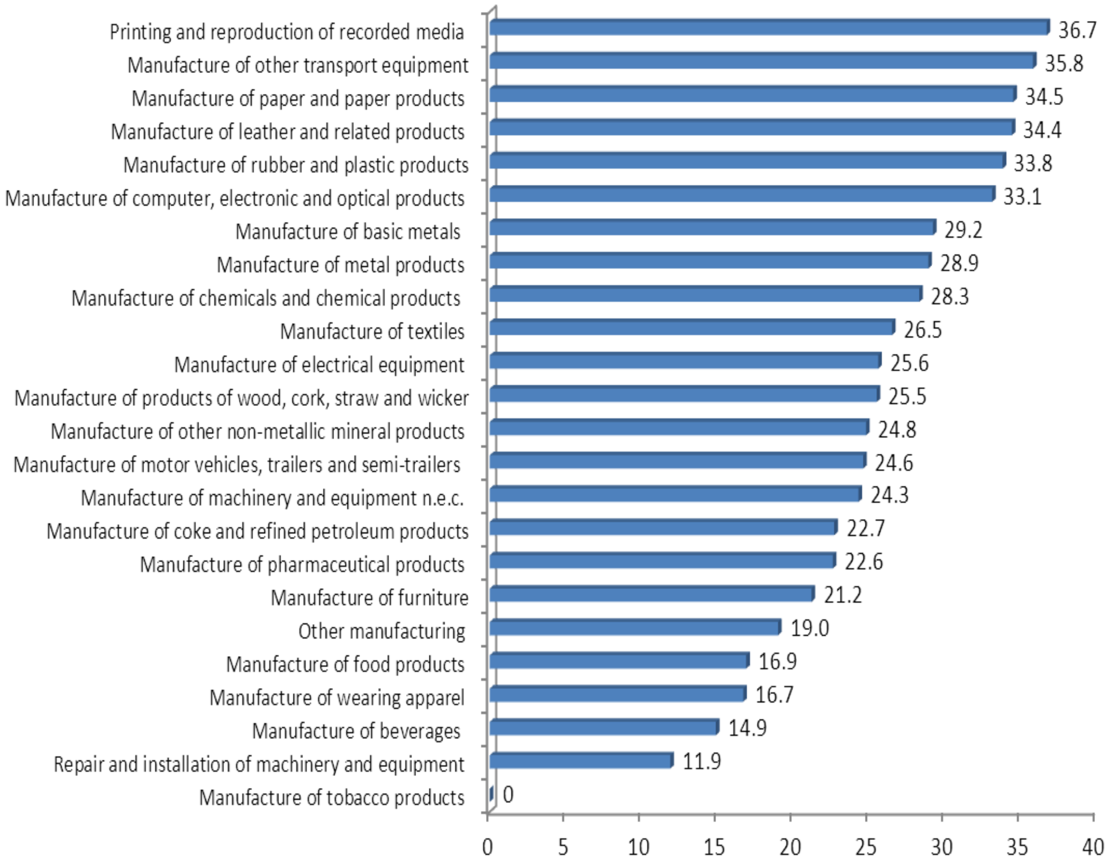
In accordance with the recommendations of the Oslo Manual, the index to evaluate the effects of the company's innovative activity is the share of revenues from the sale in the given year of new or significantly improved products, launched onto the market in the past three years, in the value of total revenue. This indicator provides important information about the impact of product innovations on the overall structure of income and the level of innovation of the enterprise [*Działalność innowacyjna przedsiębiorstw w latach 2009-2011* (Innovation Activities of Enterprises in 2009-2011), CSO, p. 49]. In the study, this index (X9) was classified as the second in the group of diagnostic indicators. In 2011 the share of revenues from the sale of new or significantly improved products in the total sales achieved by manufacturing enterprises fluctuated from 1.8% in the division of *Manufacture of apparel* to 21.5% in *Manufacture of other transport equipment*. Regrettably, in most divisions (i.e. in 14 divisions), the share of revenues from the sale of innovative products did not exceed 10% (see: Fig. 2)

Figure 2. The share of revenues from the sale of new or significantly improved products in manufacturing companies in total sales revenues by the divisions of the Polish Classification of Activity in 2011



Source: own elaboration

Figure 3. Manufacturing companies which in the years 2009-2011 received state aid for innovative activity in % of innovatively active manufacturing companies by the divisions of the Polish Classification of Activity

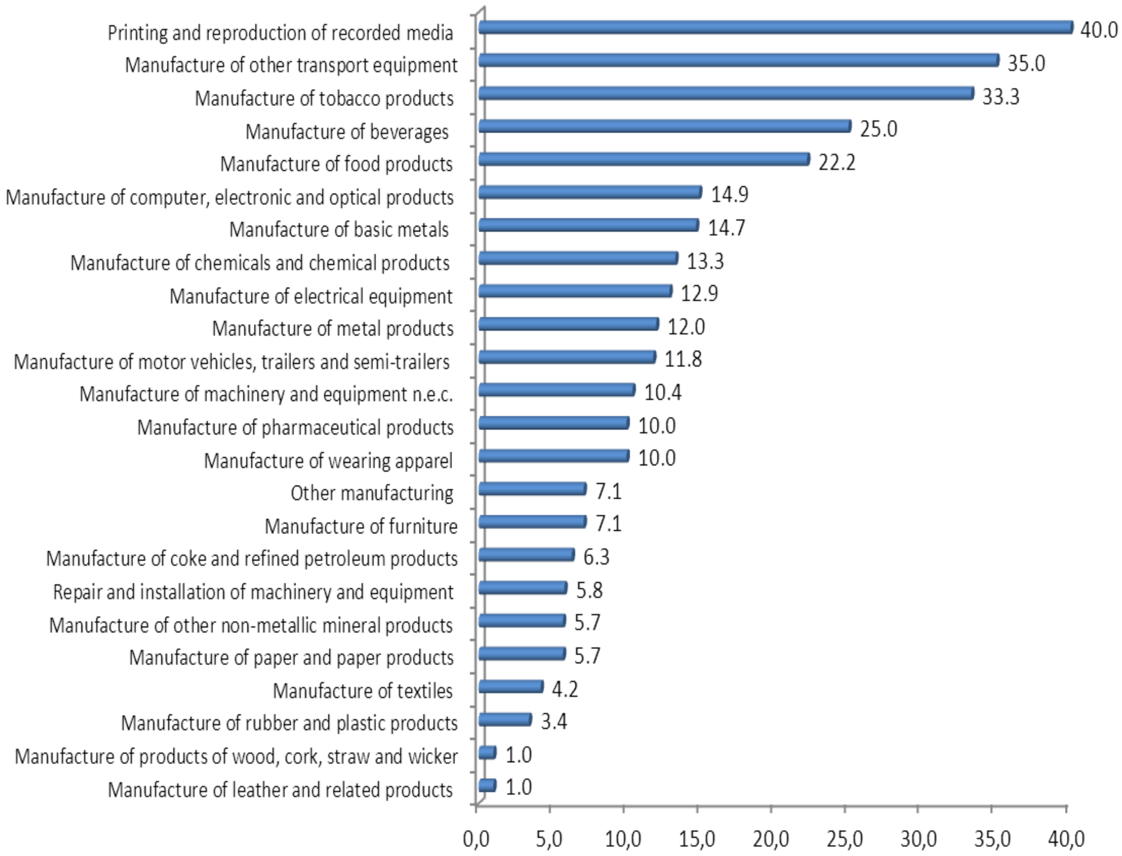


Source: own elaboration

Another indicator adopted for the analysis was the percentage of companies that have received state aid for innovative activity in the total number of innovatively active enterprises (X10). In terms of the type of business activity, it can be noted that the share of manufacturing companies that have received state aid for innovative activity in the total number of innovatively active manufacturing companies was the highest in the division of *Publishing and reproduction of recorded media*, where every third innovatively active company received state aid. The following divisions were characterised by a similar, yet slightly lower, share: *Manufacture of other transport equipment* (35.8%), *Manufacture of paper and paper products* (34.5%), *Manufacture of leather and leather goods* (34.4%), *Manufacture of rubber and plastic products* (33.8%) and *Manufacture of computer, electronic and optical products* (33.1%). The lowest percentage of companies availing of state aid was recorded in the division of *Repair, maintenance and installation of machinery and equipment* (11.9%).

The fourth diagnostic indicator (X12) is the share of manufacturing enterprises which in the years 2009-2011 cooperated in a cluster initiative in the field of innovation activity. Cooperation with other entities is an important part of the company’s business activity and it enables greater access to knowledge and new technologies. It also allows the reduction of costs and business risk, as well as promotes the exchange of experiences and knowledge. In the analysed period, the cooperation in the framework of cluster initiative was most often undertaken by companies from the division of *Publishing and reproduction of recorded media* (40%). The second place was taken by companies from the division of *Manufacture of other transport equipment* (35%), and the third place by enterprises manufacturing tobacco products (33.3%). The difference of 36.6 percentage points was recorded between companies manufacturing rubber and plastic products, which undertook cooperation in the cluster framework least often, and companies from the divisions marked by the highest index (see: Fig. 4)

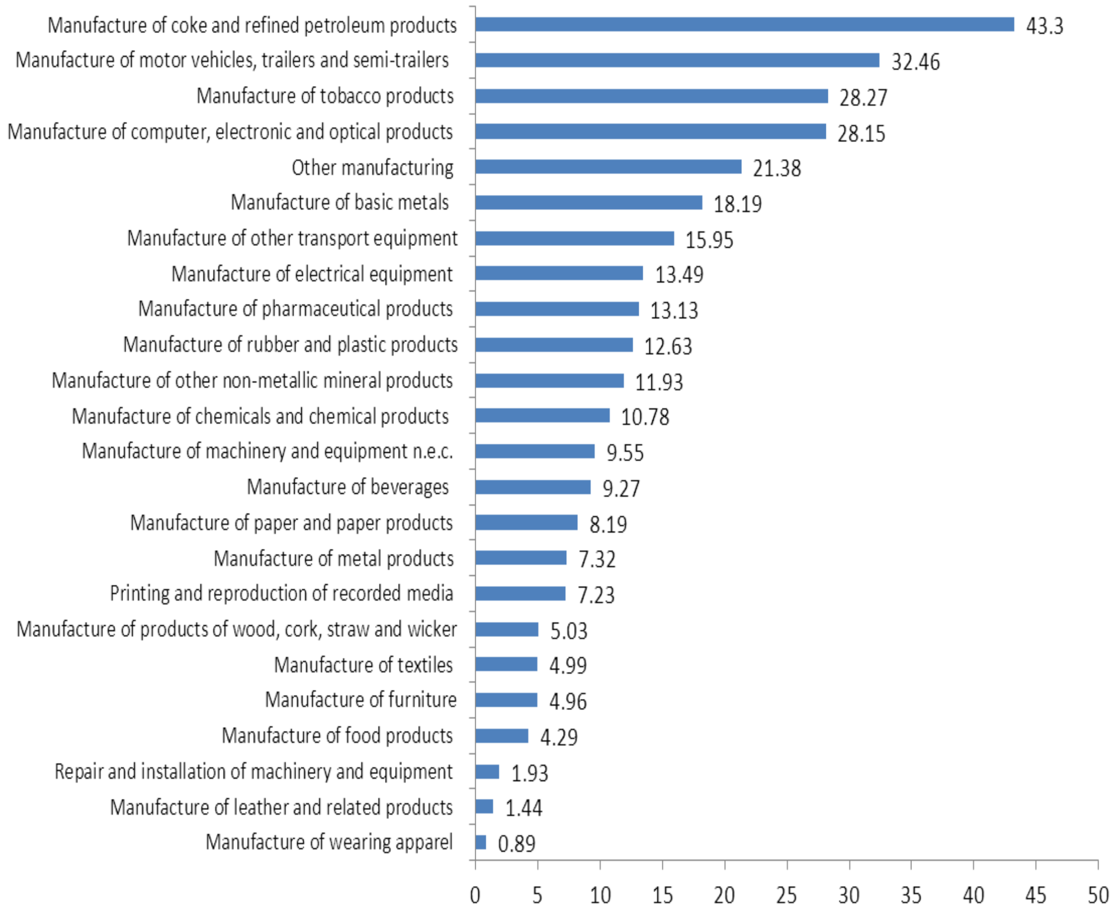
Figure 4. Manufacturing companies which in the years 2009-2011 cooperated in the framework of cluster initiative in the field of innovative activity as a percentage of companies cooperating in terms of innovative activity by the divisions of the Polish Classification of Activity



Source: own elaboration

From the perspective of the number of automated means of controlling production processes installed per company (X13), companies from the division of *Manufacture and processing of coke and refined petroleum products* clearly stood out. Approx. 43 pieces of automated means of controlling production processes per company were installed in these enterprises. The term automated means of controlling production processes encompasses devices (or combinations of machines and equipment) that perform certain tasks without human intervention. The following divisions were also characterised by relatively high automation of production processes: *Manufacture of vehicles, trailers and semi-trailers* (32 items/company), *Manufacture of* *tobacco products* (28 items) and *Manufacture of computer, electronic and optical products* (28 items). The smallest number of automated means of controlling production processes were installed in divisions traditionally considered as very labour-intensive: *Manufacture of apparel* – 0.89 items, *Manufacture of leather and leather goods* – 1.44 items (see: Fig. 5)

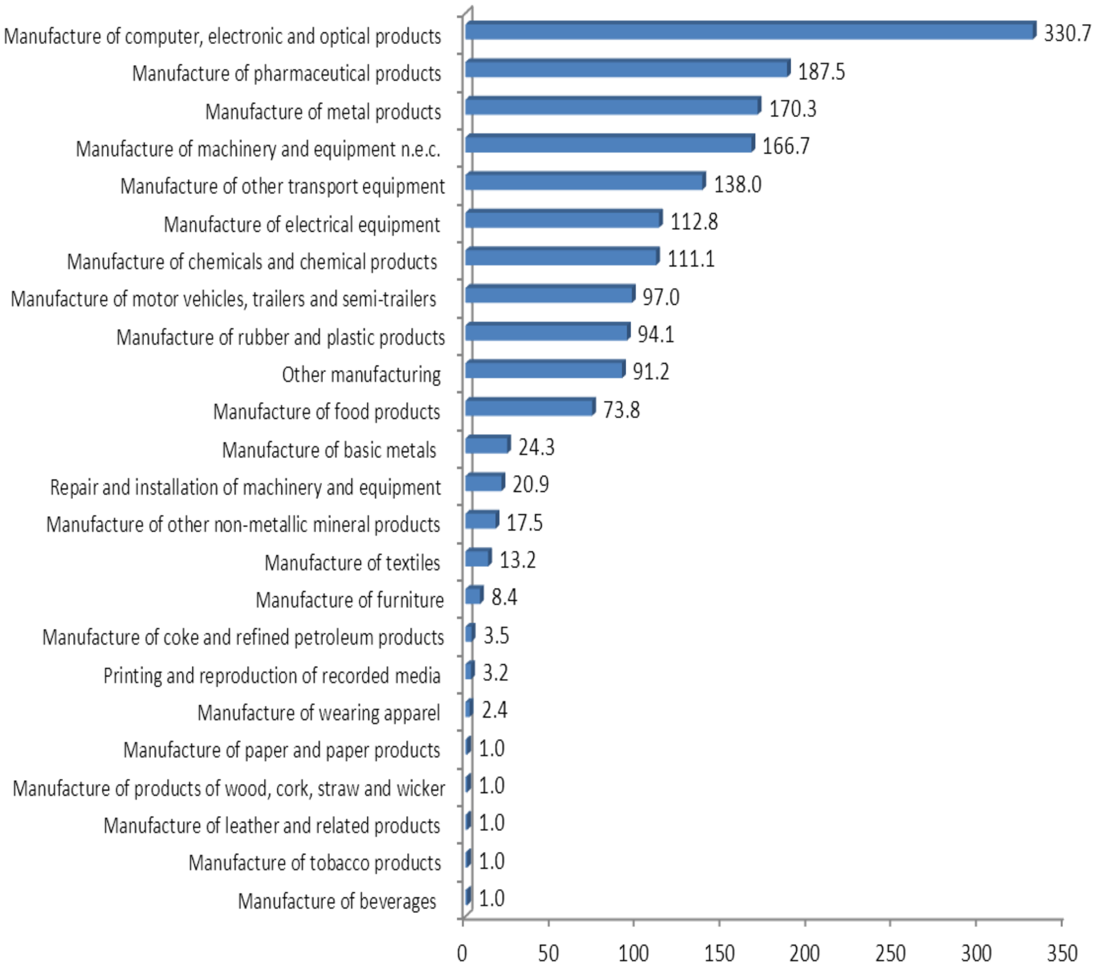
Figure 5. The number of automated means of controlling production processes installed per company in 2011 by the divisions of the Polish Classification of Activity



Source: own elaboration

The last diagnostic indicator adopted for the analysis concerns the most important category of expenditures on innovation, i.e.: internal expenditures on R&D, encompassing the value of research and development activities in the given entity carried out with the use of its own research base. The data presented in Fig. 6 indicate that internal expenditures on R&D were characterised by a great diversity. In many divisions, the level of these expenditures was virtually negligible. The highest expenditure on R&D was recorded in companies manufacturing computer, electronic and optical products (330.7 million PLN).

Figure 6. Internal expenditure on R&D in manufacturing by the divisions of the Polish Classification of Activity in 2011



Source: own elaboration

5. SYNTHETIC ASSESSMENT OF DIVISIONS OF MANUFACTURING IN POLAND IN THE YEARS 2009–2011

In determining synthetic measures of innovativeness of manufacturing companies in Poland in the years 2009–2011, the system of equal weights (see: formula 4) was adopted and the calculations were carried out in two variants with the use of: unitarisation of diagnostic indicators (variant I) and classical standardisation of diagnostic indicators (variant II) – see Table 2 and 3. In the calculations, aggregation of the diagnostic indicators by adding up the normalised values was carried out. It yields exactly the same result of linear ordering of objects as aggregation according to the arithmetic mean of normalised values of diagnostic indicators (see: formula 9).

Table 2. Numeral characteristics of linear ordering of manufacturing companies with the assessment of the quality of ordering for variant I – unitarisation of diagnostic indicators

Manufacture division	**Synthetic measure** M	**Values** $\left(\mu_i^* - \bar{\mu}^*\right)^2$
	2009-2011	**2009-2011**
Manufacture of food products	1.253	0.0028
Manufacture of beverages	1907	0.0001
Manufacture of tobacco products	2.181	0.0001
Manufacture of textiles	1.054	0.0044
Manufacture of apparel	0.452	0.0116
Manufacture of leather and leather goods	1.149	0.0036
Manufacture of wood and cork products, excl. furniture; manufacture of straw products and plaiting materials	0.849	0.0065
Manufacture of paper and paper products	1.954	0.0000
Publishing and reproduction of recorded media	2.609	0.0015
Manufacture and processing of coke and refined petroleum products	3.037	0.0047
Manufacture of chemicals and chemical products	2.967	0.0040
Manufacture of basic pharmaceutical substances, medicines and other pharmaceutical products	2.852	0.0031
Manufacture of rubber and plastic products	1.875	0.0001
Manufacture of other non-metallic mineral products	1.,435	0.0017
Manufacture of metals	2.011	0.0000
Manufacture of ready-made metal products, excl. machines and devices	2.105	0.0000
Manufacture of computer, electronic and optical products	3.566	0.0109
Manufacture of electrical equipment	2.484	0.0009
Manufacture of machines and devices not elsewhere classified	2.385	0.0006
Manufacture of vehicles, trailers and semi-trailers, excl. motorcycles	2.928	0.0037

Manufacture of other transport equipment	4.020	0.0183
Manufacture of furniture	1.219	0.0031
Other manufacturing	1.811	0.0002
Repair, maintenance and installation of machinery and equipment	0.695	0.0083
$s^2(M^*)$	X	**0.0038**

Source: own elaboration

The next table presents the results of linear ordering of manufacturing companies for variant II (classical standardisation of diagnostic indicators).

Table 3. Numeral characteristics of linear ordering of manufacturing companies with the assessment of the quality of ordering for variant II – classical standardisation of diagnostic indicators

Manufacture divisions	**Synthetic measure** M	**Values** $(\mu_i^* - \bar{\mu}^*)^2$
	2009-2011	**2009-2011**
Manufacture of food products	-3.126	0.0452
Manufacture of beverages	-0.811	0.0030
Manufacture of tobacco products	0.401	0.0007
Manufacture of textiles	-3.906	0.0706
Manufacture of apparel	-6.209	0.1785
Manufacture of leather and leather goods	-3.635	0.0612
Manufacture of wood and cork products, excl. furniture; manufacture of straw products and plaiting materials	-4.736	0.1038
Manufacture of paper and paper products	-0.467	0.0010
Publishing and reproduction of recorded media	1.856	0.0159
Manufacture and processing of coke and refined petroleum products	3.734	0.0646
Manufacture of chemicals and chemical products	3.166	0.0464
Manufacture of basic pharmaceutical substances, medicines and other pharmaceutical products	2.772	0.0356
Manufacture of rubber and plastic products	-0.765	0.0027
Manufacture of other non-metallic mineral products	-2.438	0.0275
Manufacture of metals	-0.306	0.0004
Manufacture of ready-made metal products, excl. machines and devices	0.190	0.0002
Manufacture of computer, electronic and optical products	5.832	0.1575
Manufacture of electrical equipment	1.632	0.0123
Manufacture of machines and devices not elsewhere	1.329	0.0082

classified		
Manufacture of vehicles, trailers and semi-trailers, excl. motorcycles	3.516	0.0572
Manufacture of other transport equipment	7.427	0.2554
Manufacture of furniture	-3.239	0.0486
Other manufacturing	-0.871	0.0035
Repair, maintenance and installation of machinery and equipment	-5.102	0.1205
$s^2(M^*)$	X	**0.0550**

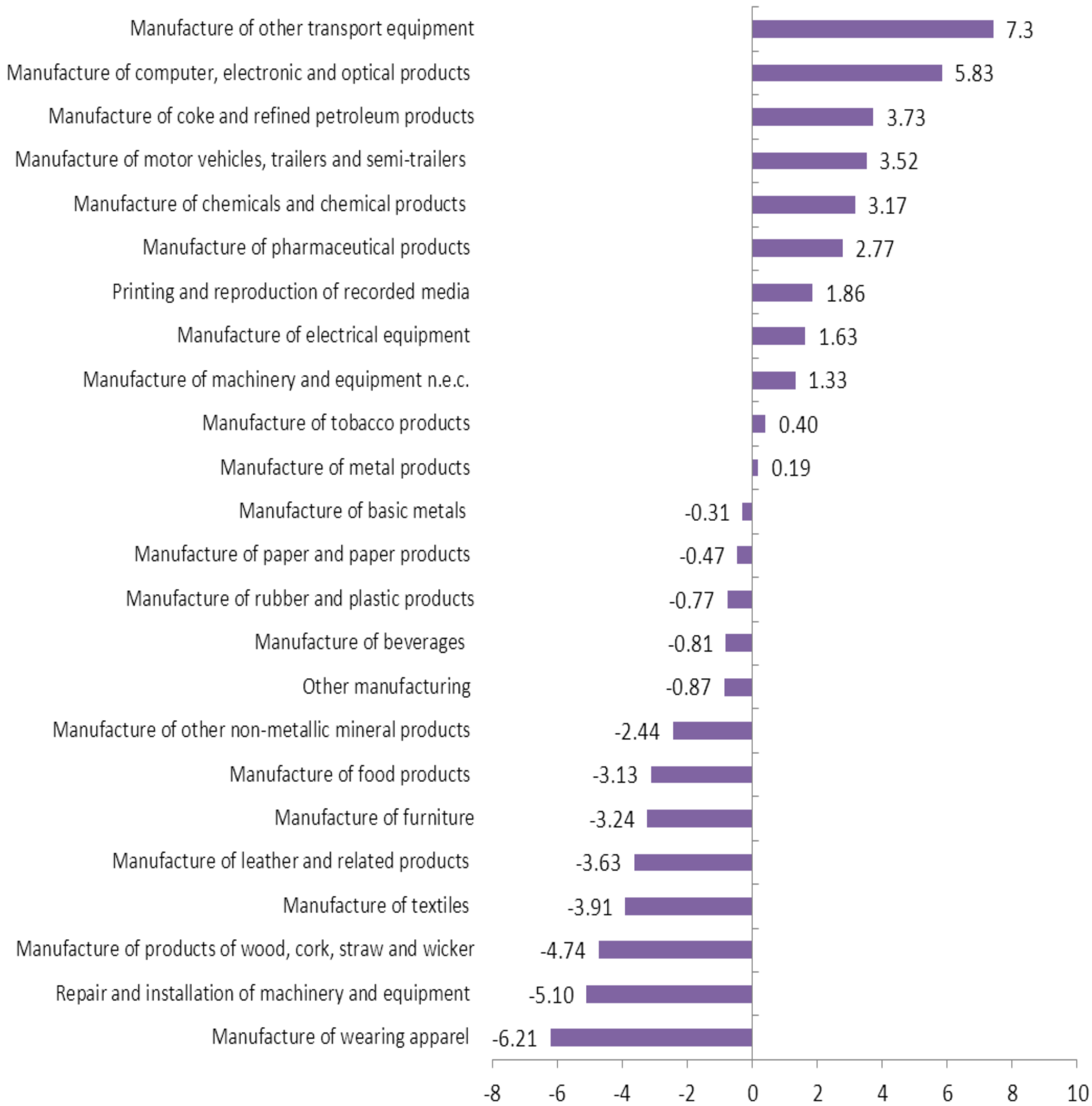
Source: own elaboration

Based on the criterion of maximising the directional variance of the synthetic measure, which in this case required the transformation of the value of synthetic measure M into the result of the orthogonal projection of objects onto the line M^*, the results obtained in variant II of the analysis were deemed as a “better” ranking of innovativeness of manufacturing companies – see Table 2 and 3.

The correlation analysis of the diagnostic indicators with the values of the synthetic measure indicated the agreement of the direction of correlation (positive correlation) and the strength of the impact of the indices on the value of the measure, which indicates the correct selection of variables for the analysis. Among the diagnostic indicators, the least correlated with the synthetic variable were the values of index X12 – the share of enterprises that have cooperated in a cluster initiative in the field of innovation activity.

The assessment of innovativeness conducted with the use of statistical methods of linear ordering of objects allows the construction of a ranking of innovativeness of manufacturing companies in Poland in the years 2009-2011 according to the divisions of the Polish Classification of Activity. Figure 7 presents the manufacture divisions organised by the level of their innovativeness measured with the synthetic index.

Figure 7. Ranking of innovativeness of manufacturing companies in Poland in the years 2009-2011 by the divisions of the Polish Classification of Activity (classical standardisation)



Source: own elaboration

6. CONCLUSIONS

The conducted study indicates that in the years 2009-2011 the most innovative, in the light of the diagnostic indicators adopted for the purpose of this analysis, were the enterprises from the division of *Manufacture of other transport equipment* (building of ships and boats, manufacture of railway locomotives and rolling stock, manufacture of military fighting vehicles). The second place in the ranking was taken by companies manufacturing computer, electronic and optical products. Companies manufacturing and processing coke and refined petroleum products ranked third. Enterprises manufacturing vehicles, trailers and semi-trailers, as well as companies from the chemical and pharmaceutical sector, were characterised by relatively high innovativeness. Innovativeness of the other types of manufacturing was visibly lower. Enterprises manufacturing apparel ranked last in the ranking of innovativeness.

The level of innovativeness, thus also the development of the Polish manufacturing industry, still lags behind more developed countries. One of the greatest weaknesses of the national innovation system in Poland is the low level of expenditures on R&D and their unfavourable structure. Studies on the presence and significance of foreign manufacturing capital in the Polish manufacturing industry also indicate that its impact on the increase of innovativeness of the national industry does not fully meet the expectations [Talar 2006, pp.17-18]. Foreign capital is not greatly interested in developing in Poland production that requires intensive use of human capital, which is a negative phenomenon for the development of science-intensive areas of production.

The conducted study should provide certain recommendations concerning the future policy for supporting innovative activities of manufacturing companies in Poland.

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