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Discriminant Analysis in Polish Manufacturing Sector Performance Assessment

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Abstract
This is the presentation of the preliminary results of the manufacturing branches attractiveness. Results of Polish manufacturing branches performance assessment in 2000 (the section D „Manufacturing” – based on NACE – Nomenclatures des Activités de Communauté Européene) are shown. The research, the classical (Fisher’s) linear discriminant analysis technique was used for the analysis of the profit generation ability by the firms belonging to the certain production branch. For estimation the data describing Groups level was used – cross-validation, the Classes data.

1. Introduction
In recent years in Poland the demand for the information describing situation of the individual industries or branches (the branch is understood as unit, group or class) is rapidly growing. During recent years – authors were working on the assessment of the Polish manufacturing branches performance. As the result some papers were presented (ASMDA Compiegne 2001, GfKI Munich 2001). Selected financial indicators were used for manufacturing branches clustering and ordering in accordance with their attractiveness from investors’ point of view. The open question remains – which financial indicators may be used to guarantee branches comparability? The results of discriminant analysis applied to the branches situation assessment. The technique choice was determined by the attempt to solve the comparability of the financial indicators for specific economic activity area. It has been assumed that if the use of the discriminant function leads to true classification of individual objects (Branch) – it means that the financial indicators used for discriminant function construction are comparable. Additionally one may check in this manner, which indicators have discriminative properties.

The classic Fisher linear discriminant analysis technique was chosen because of its numerous advantages, including: robustness over time, interpretability and straightforwardness. The specific use of the discriminant function for the manufacturing branches assessment may be formulated as follow.

— Having the discriminant function that was estimated on the data from the given time period – the future situation of objects (e.g. enterprises) may be assessed.

— Having the discriminant function that was estimated on the data from the higher level of NACE classification (e.g. Groups) – objects belonging to lower level (e.g. Classes) are classified. It may go as far down as the enterprise.

The goal of the analysis here is the application of the later task. This is due to severe problems with the data on low aggregation levels.

2. The Data
The Polish Central Statistical Office (GUS) collects the data describing the enterprise’s condition on the quarterly and yearly basis. In order to assess branch condition – the situation of individual firms belonging to this branch are to be examined. To cover all aspects of the enterprises activity the following areas should be included into analysis: sales tendency; liquidity; debt situation; efficiency and profitability. Corporate finance and managerial accounting literature gives a variety of measures describing the management quality (see [2, 5]). The following indicators have been chosen for the analysis – the nature of the variable (stimulant, destimulant; nominant) and suggested nominal values are stated:

1) SALE’S TENDENCY ANALYSIS – X₁ the dynamics of incomes from sale in fixed prices from January 2002 – chain base index – analogous period previous year = 100%, stimulant;
2) LIQUIDITY ANALYSIS – X₂ current ratio (current assets / current liabilities), nominant with recommended value range [1.2 - 2.0]; X₃ quick ratio (current assets – inventories / current liabilities), nominant with recommended value range [1.0 - 1.5]; X₄ finished goods inventory utilization ratio in days (finished goods inventory / sales * 360), destimulant; X₅ cash (financial means) cycle ratio in days (inventory turnover + receivable turnover – accounts-payable turnover), destimulant;
3) DEBT ANALYSIS – X₆ debt ratio (total debt / total assets), nominant with recommended value range [0.57 - 0.67]; X₇ debt-equity ratio (total debt / equity), nominant with recommended value range [1.0 - 3.0]; X₈ long-term debt ratio (long-term debt / equity), nominant (6,5);
4) EFFICIENCY ANALYSIS – X₉ cost ratio (prime cost of sales / sales), destimulant or stimulant with threshold value 1; X₁₀ fixed assets utilization ratio (sales / fixed assets), stimulant; X₁₁ productivity on one employee (sales / average number of employees), stimulant;
5) PROFITABILITY ANALYSIS – X₁₂ profit margin on sales (net income / sales), stimulant or stimulant with threshold value 0; X₁₃ return on assets (net income / total assets), stimulant or stimulant with veto threshold value 0; X₁₄ return on equity (net income / equity), stimulant or stimulant with veto threshold value 0.

The research was carried out on data gathered according to the NACE. For the evaluation of the Polish manufacturing sector performance the data for the branches from the statistical reports collected by the Polish Central Statistical Office have been used. The yearly data from 2000, for 92 groups and for 181 classes of Section D (Manufacturing) was used.
3. The analysis

With accordance with the goal of the research the discriminant function is constructed in order to predict the profit generation ability by the enterprises. The discriminant function constructed is based on the data aggregated to the level of Groups. The discrimination criterion dividing the whole Groups entity on two subpopulations was the profit level. Depending whether the profit was positive or negative - the Groups population (92 in total) was divided into two subpopulations. Out of them there were:

\( \pi_0 \) - subpopulation of manufacturing Groups with positive net profit in year 2000 - altogether 52 objects (Groups),

\( \pi_1 \) - subpopulation of manufacturing Groups with net loss in year 2000 - altogether 40 objects (Groups).

For the discriminant function construction the financial indices shown in section 2 were used. Because of the adopted discrimination criterion (profit level) - the list of indicators was modified in the way that the indicators describing profitability (i.e. variables \( x_{12}, x_{13}, x_{14} \)) were eliminated.

The variables that were used for the discriminant function construction (i.e. variables \( x_1 \) - \( x_{11} \)) the routine testing procedures were conducted. In particular the cross correlation as well as the mean equality and the normality of the distribution were examined. As the result the observation occurred that only variable \( x_6 \) (debt ratio) is normally distributed. Researchers very frequently report, that most of the economic variables are not normally distributed. In spite of the fact that the variables are not normally distributed - all eleven variables were taken for further analysis. In case of variables \( x_8 \) and \( x_{11} \) mean equality testing show the lack of significant differences between arithmetic means in two subpopulations - this in turn leads to the conclusion that those two variables are lacking of the discriminative features - they were omitted in the analysis. For the reminder of the variables the cross correlation was examined. In most cases the correlation was low.

Using standard forward stepwise and backward stepwise procedures offered by the STATISTICA package the discriminant function was estimated. This results in specific, iterative variable selection for the model. The task is that in the model only variables with strong discriminating power are included. In the standard forward stepwise procedure - at the starting point there is only one variable in the model. In the next step the next (one) variable is added. The choice criterion for the inclusion is the increase of the Mahalanobis distance between subpopulations. In the standard backward stepwise procedure - at the starting point all variables are in the model. In the next step one variable is omitted. The choice criterion for the omitting is the increase of the Mahalanobis distance between subpopulations.

Here, both procedures lead to the same list of variables included in the discriminant function. These are: \( x_9 \) cost ratio, \( x_3 \) liquidity quick ratio, \( x_7 \) debt-equity ratio, \( x_{11} \) cash (financial means) cycle ratio. Variables are listed with accordance with their declining discriminative power.

Two versions of data were used for discriminant function estimation - raw and standardised. From practical point of view the discriminant function based on the raw data is more convenient. On the other hand the parameter estimates depend on variables measurement units. In contrast the discriminant function estimation based on standardised observations show the weights each variable contributes to the discrimination criterion. It allows the relative impact comparison on the discrimination criterion - high absolute value of the parameter estimate indicates heavy impact of the variable on the discriminative power of the discriminant function.

Equation (1) and (2) shows the discriminant function estimation results for raw data \( M(O) \) and standardised data \( M(S) \):

\[
M(O) = -18.215x_9 + 1.792x_3 - 0.394x_7 - 0.006x_5 + 17.391
\]

\[
M(S) = -0.726x_9 + 0.389x_3 - 0.260x_7 - 0.216x_5 + 1.332
\]

Standard statistical evaluation of the discriminant function requires discriminant power assessment of the whole function as well as the individual variables. For the discriminative power assessment of the discriminant function the Wilks' lambda statistics \( \lambda \) has been used. Lambda statistics have values from the \([0; 1]\) interval and its low value proves high discriminative power of the function. For the discriminative power assessment of the individual (k-th) variable the Wilks' partial lambda statistics \( \lambda_k \) and tolerance value have been used. Partial lambda statistics measures the impact of the individual variable on the composite value of the statistics lambda \( \lambda \) (how much will the value of statistics \( \lambda \) increase provided k-th variable is driven out of the discriminant function). The tolerance value was computed as \((1 - R_k^2)\) of the k-th variable with all other variables included in the model (the proportion of variance that is unique to the k-th variable).
For the obtained discriminant function the obtained Wilks' statistics lambda $\Lambda = 0.42880$ with corresponding statistics $F(4; 87) = 28.973$, $p = 0.000$. The additional model's characteristics are given in the Table 1. They indicate low cross correlation of financial indicators used for the discriminant function construction as well as the significance of used variables.

Table 1. Discriminant function quality measures

<table>
<thead>
<tr>
<th>lambda</th>
<th>F(1, 87)</th>
<th>Significance level p</th>
<th>Tolerance value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X9</td>
<td>0.577</td>
<td>29.910</td>
<td>0.000</td>
</tr>
<tr>
<td>X3</td>
<td>0.459</td>
<td>6.176</td>
<td>0.016</td>
</tr>
<tr>
<td>X7</td>
<td>0.443</td>
<td>2.803</td>
<td>0.086</td>
</tr>
<tr>
<td>X5</td>
<td>0.440</td>
<td>2.212</td>
<td>0.141</td>
</tr>
</tbody>
</table>

Source: Own computation.

Classification matrix shown in the Table 2 illustrates the classification accuracy for the analytical data (Group level, data used for function estimation). There were 95.7% properly classified objects. For the objects with positive financial result (net profit) this accuracy was higher – out of 52 manufacturing Groups only one was wrongly classified (i.e. 98.1% accuracy). In the case of 40 manufacturing Groups with negative financial result (net loss) the classification accuracy was lower i.e. 92.3%.

Table 2. Classification accuracy for analytical data set

<table>
<thead>
<tr>
<th>Properly classified objects (in %)</th>
<th>p=0.56</th>
<th>p=0.44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 0</td>
<td>98.1</td>
<td>51</td>
</tr>
<tr>
<td>Group 1</td>
<td>92.5</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>95.7</td>
<td>34</td>
</tr>
</tbody>
</table>

Source: Own computation.

Full assessment of the discriminant function quality requires that for validation a different data set is used, different than analytical one i.e. data set used for estimation of the function. As the validation data set a population of 181 manufacturing Classes was used. It was known, to which subpopulation the individual object (Class) was belonging. The subpopulation piZero – consisted of 97 objects, and subpopulation piOne consisted of 84 Classes. Cross-validation on the validation data set indicates additionally the robustness and applicability of the discriminant function. Classification matrix for validation data set is shown in the Table 3.

Table 3. Classification accuracy for validation data set

<table>
<thead>
<tr>
<th>Properly classified objects (in %)</th>
<th>p=0.56</th>
<th>p=0.44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0</td>
<td>86.6</td>
<td>84</td>
</tr>
<tr>
<td>Class 1</td>
<td>83.3</td>
<td>70</td>
</tr>
</tbody>
</table>

Source: Own computation.

No improvement potential additional exercise has been made. A new discriminant function has been constructed. As the analytical data set the 181 objects (Classes level) was used. The new discriminant function consists of the same financial indicators as the previous one. Of the variables x5, x7, x1, which were included in previous function, there was only one additional indicator included (X4, finished goods inventory utilization ratio – with lowest discrimination power). This new discriminant function classifies properly 86.4% objects. The improvement in comparison with previous version of discriminant function is very small, only some 1.4%. This means that there is no need to go to very low aggregation level while constructing discrimination function.

The further research requires analysis of the discrimination accuracy for the individual enterprises as well as the possibility of the profit generation ability prediction.

4. References