MULTIDIMENSIONAL STATISTICAL METHODS FOR STUDY OF COMPETITIVENESS OF FORESTRY COMPANY

Konstantin Kolev
University of Forestry, Sofia, Bulgaria

Abstract

One of the relevant priorities of the Strategic Plan for Development of Bulgarian Forest Sector 2014-2023 is to increase the competitiveness of the forest sector as a basis for a better standard of living, especially in the mountainous and rural regions of the country [5]. Quantifying the competitiveness of business entities in forestry allows scientifically sound business decisions by means of which competitiveness at the enterprise level will be increased and through it the competitiveness at sector level also. In this regard, the purpose of this article is to compare two multidimensional statistical methods – factor analysis and linear ordering in multidimensional space as possible approaches for quantification of competitiveness of forestry company.

Key words: competitiveness, factor analysis, linear ordering in multidimensional space, forestry.
JEL: C40, C43.

Introduction

Increasing the competitiveness of forestry is precondition for better standard of living especially in mountainous and rural regions of Bulgaria [5]. The competitiveness of the sector is derived from the competitiveness of the economic entities operating in it. Quantifying the competitiveness of the latter allows scientifically sound business decisions by means of which competitiveness at the enterprise level will be increased and through it the competitiveness at sector level. There are different methods for estimation of company's competitiveness, but no one is generally accepted. The main disadvantages of most of them are the lack of complexity in the assessment and the inability to achieve general assessment standardized within certain limits [11]. These shortcomings are expected to be overcome through the use of multidimensional statistical methods, which are applied by the World Economic Forum (WEF) and the Institute for Management Development (IMD) in the process of elaboration of the two globally recognized indices for assessing national competitiveness and namely Global Competitiveness Index (GCI) and World Competitiveness Yearbook (WCY) index [7]. Concerning this the goal of current article is to compare two classical multidimensional statistical methods – factor analysis and linear ordering in multidimensional space as possible approaches for quantification of competitiveness of forestry company.

1. Factor analysis

The analytical model of factor analysis is presented through formula (1) [4]:

$$
\begin{aligned}
z_{i(1)} &= b_{1(1)}F_{i1} + b_{1(2)}F_{i2} + \ldots + b_{1(m)}F_{im} + e_{i(1)} \\
z_{i(2)} &= b_{2(1)}F_{i1} + b_{2(2)}F_{i2} + \ldots + b_{2(m)}F_{im} + e_{i(2)} \\
&\ldots \\
z_{i(p)} &= b_{p(1)}F_{i1} + b_{p(2)}F_{i2} + \ldots + b_{p(m)}F_{im} + e_{i(p)}
\end{aligned}
\qquad (1)
$$

where $z_{i(j)}$ are the standardized value of the j-th indicator/variable at the i-th forestry company (see formula (6)).

$F_{i(q)}$ – the values of the common factors;

m – the number of the common factors;

p – the number of initial variables;

n – the number of observations;

$b_{j(q)}$ – factor loading. It is the coefficient of correlation between the j-th initial indicator/variable and q-th factor;

$e_{i(j)}$ – unique factors, which present the unique part in each initial variable.

The square of the factor loading ($b^2_{j(q)}$) is a coefficient of determination, which measures the variation of the j-th variable/indicator explained with the q-th factor influence. The sum of the squares of factor loadings is known as communality (see formula (2)). It presents the contribution of each variable/indicator towards all factors formation in the factor's scheme [4].

$$b^2_j = \sum_{q=1}^{m} b^2_{j(q)}, \quad j = 1 \ldots p \qquad (2)$$

The extraction of factors is done by the method of principal component analysis (PCA) and unit criterion of Kaiser. According to it, as factors have to be extracted only these main components with eigenvalues higher than 1. The eigenvalue measures the proportion of variance in the variables explained by the respective factor. The eigenvalue is computed by means of formula (3) [2, 4]. In this paper the PCA is accepted as it extracts maximum variance from the data set with each component and in this way reduce a large number of variables into a smaller number of components [15] and permits ease of interpretation. In this relation it should be noted that 'in reality researchers often use more than one extraction and rotation technique based on pragmatic rather than theoretical reasoning [15].

$$l_q = \sum_{j=1}^{p} b_{j(q)}^2, \;\; j = 1...p \qquad (3)$$

where l_q is the eigenvalue of the q-th factor.

After the extraction of factors and their rotation, if it is necessary (the rotation is necessary for better interpretation when the unrotated factors are ambiguous) the factors scores can be calculated. They are the latent scores for each subject from the representative sample on each factor, i.e. each unit from the sample has an individual factor score on each factor. For factors score computation the matrix is applied, in which common factors are dependent variables and the initial variables are independent (see formula 4) [4]. The values of factors scores range from approximately -3.0 to +3.0 [1].

$$\begin{aligned} \hat{F}_{i(1)} &= f_{1(1)} z_{i1} + f_{1(2)} z_{12} + ... + f_{1(p)} z_{ip}, \; i = 1..n \\ \hat{F}_{i(2)} &= f_{2(1)} z_{i1} + f_{2(2)} z_{12} + ... + f_{2(p)} z_{ip}, \; i = 1..n \qquad (4) \\ &... \\ \hat{F}_{i(m)} &= f_{m(1)} z_{i1} + f_{m(2)} z_{12} + ... + f_{m(p)} z_{ip}, \; i = 1..n \end{aligned}$$

where $\hat{F}_{i(q)}$ is the factor score of i-th subject from the sample on q-th factor;

$f_{q(j)}$ – factor score coefficients. They are analogous to beta weights in the regression equation. There are different methods for factor score coefficients computation – regression method, Bartlett method and Anderson-Rubin method [1]. In this paper there is no matter which methods of the mentioned above will be used as when the factors are extracted through PCA application the same factor score coefficients are obtained regardless of the method used [4].

After the factor scores are established, the index of forestry company competitiveness (I_{fcc}) may be computed. It is done through linear aggregation of the factor scores on different factors extracted, weighted with weights determined by factor analysis [3, 10].

$$I_{fcc} = \sum_{q=1}^{m} \hat{F}_q w_q \qquad (5)$$

where I_{fcc} is the index of forestry company competitiveness;

w_q – the weight of q-th factor. It is established as the eigenvalue of the q-th factor (explained variance) is divided by total variance ($l_q/\sum l_q$).

2. Linear ordering in multidimensional space

Linear ordering in regard to complex indicator competitiveness is done on the basis of point-pattern in multidimensional space and establishment of location of the compared forestry companies towards this point. This is used to calculate multidimensional indicators normalized within boundaries from 0 to 1. Linear ordering should be applied on the basis of accepted indicators which characterize the competitiveness of forestry company. As this indicators are expressed in various measuring units (currency, ha, m^3, etc.) their aggregation requires to be transformed from named to unnamed values. For this purpose the classic standardization formula is applied [8, 12, 14]:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j} \qquad (6)$$

where z_{ij} is the standardized value of the j-th indicator at the i-th forestry company;

x_{ij} is the value of the j-th indicator at the i-th forestry company;

σ_j – standard deviation of the j-th indicator.

Linear ordering is done on the basis of the standardized values of the indicators and the coordinates of the pattern point in m-dimensional space. Such are the extreme values of the standardized indicators. They are categorized as stimulators and suppressors. As regards the former, the higher value is related to the increase of the quantitative assessment of the level of the multivariate indicator (competitiveness), while regarding the latter, it is related to its decrease. In formula (7) the stimulating indicators are taken at their maximum values and the suppressing indicators are taken at their minimum values [8, 12, 14].

$$k_{ie} = \sqrt{\sum (z_{ij} - z_{ej})^2} \tag{7}$$

where k_{ie} is the Euclidean distance between the competitiveness of the i-th forestry company and the pattern point;
z_{ij} – the standardized value of the j-th indicator of the competitiveness of the i-th forestry company;
z_{ej} – the standardized value of the j-th indicator at the pattern point.

The quantitative estimation (multivariate indicator) of the level of competitiveness of the i-th forestry company is determined through formula (8):

$$K_i = 1 - \frac{k_{ie}}{k_e} \tag{8}$$

where K_i is the multivariate indicator (index of forestry company competitiveness (I_{fcc})) of the level of competitiveness of the i-th forestry company;
k_e – sum of the mean value of the Euclidean distances determined through formula (7) and their doubled standard deviation.

3. Application of factor analysis and linear ordering in multidimensional space

The sensitivity of both methods – factor analysis and linear ordering in multidimensional space is compared on the basis of standardized values of six indicators (Y_1, Y_2, Y_3, Y_4, Y_5, Y_6) characterizing competitiveness of 14 forestry companies. The standardized values of indicators are presented in table 1.

Table 1. Standardized values of indicators characterizing competitiveness

Forestry company	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
A	-0.168	-0.509	-0.159	-0.470	-0.090	0.942
B	-0.828	-0.529	-0.785	-0.866	-0.925	-1.245
C	-1.006	-0.689	-1.087	-1.094	-0.860	-1.153
D	-1.136	-0.936	-1.606	-1.392	-0.948	-1.337
E	-0.068	-0.668	-0.643	-0.642	-0.317	-0.622
F	0.949	1.724	1.393	2.037	1.426	2.841
G	1.719	1.084	1.741	1.651	0.225	1.111
H	2.549	0.360	3.062	2.964	0.524	0.626
I	-0.020	0.324	0.254	-0.198	0.319	-0.567
J	-0.615	-0.405	-1.377	-0.692	-0.409	-0.036
K	-0.397	-0.165	0.181	-0.318	-0.577	-1.053
L	-0.601	-0.753	-0.955	-0.899	-0.521	-0.974
M	-0.902	-0.832	-1.092	-1.057	-0.853	0.066
N	0.844	2.604	2.202	1.522	3.076	1.988
Coordinates of the pattern point	**2.549**	**2.604**	**3.062**	**2.964**	**3.076**	**2.841**

The results from factor analysis and linear ordering in multidimensional space application are presented in table 2. From it is clear that both methods permit nearly the same ordering in multidimensional space, which means that both methods are relevant for quantitative assessment of forestry company competitiveness. At the same time it should be underlined that the factor analysis is more selective to changes in the values of the used indicators than the method of linear ordering in multidimensional space. This statement is obvious from the values of I_{fcc} for company H and company G calculated by means of both methods.

Table 2. Index of forestry company competitiveness (I_{fcc})

№	Factor analysis		Linear ordering in multidimensional space	
	Forestry company	Index of forestry company competitiveness (I_{fcc})	Forestry company	Index of forestry company competitiveness (I_{fcc})
1	N	2.207	N	0.836
2	F	1.778	F	0.785
3	H	1.474	G	0.682
4	G	1.227	H	0.680
5	I	0.007	I	0.443
6	A	-0.177	A	0.400
7	K	-0.268	E	0.340
8	E	-0.396	K	0.335
9	J	-0.544	J	0.318
10	M	-0.786	L	0.265
11	L	-0.802	M	0.255
12	B	-0.868	B	0.242
13	C	-0.973	C	0.220
14	D	-1.179	D	0.175

Conclusion

The comparison of both methods - factor analysis and linear ordering in multidimensional space gives grounds for the statement that both methods are reliable instruments for assessment of competitiveness of forestry company as the ordering obtained by their application is nearly the same. By the way the factor analysis is more selective to changes in the values of the used indicators. Here should be underlined that the application of factor analysis has to be compliant with some conditions: Firstly, the recommended number of observations is at least 50; Secondly, in factor analysis are included correlating variables. If a variable is not correlated with the others it must be excluded from factor analysis; Thirdly, a measure of whether values distribution is adequate for factor analysis realization has be done through Kaiser-Mayer-Olkin (KMO) coefficient for sample adequacy and Bartlett Test of Sphericity [2, 4].

Acknowledgements

The publication contents results from research that is financed by Scientific and Research Sector

(НИС) of University of Forestry – Sofia, contract № НИС-Б-1140/05.04.2021.

References

1. DiStefano, Christine, Zhu, Min & Mindrila, Diana. 2009. Understanding and Using Factor Scores: Considerations for the Applied Researcher. Practical Assessment, Research & Evaluation, 14 (20), 1-11.
2. George, D., P. Mallery. 2011. SPSS for Windows Step by Step. A Simple Guide and Reference 18.0 Update. Eleventh Edition, Boston, 386 p.
3. Jelili, R. 2019. A Global Foreign Direct Investment Attractiveness Index. Dhaman, 270 p.
4. Manov, A. 2002. Multidimensional statistical methods with SPSS. University Edition ‘Stopanstvo’, Sofia, 247 p. (in Bulgarian)
5. Ministry of Agriculture and Food. 2014. Strategic plan for development of forest sector 2014-2023. Sofia, 123 p. (in Bulgarian)
6. Milchev G. 2019. "GIS in the strategy for sustainable management of enterprises", collection of reports from the 17th International Scientific Conference "Management and Engineering '17", issue 2, 647-653, ISSN 1314 -6327. (in Bulgarian)
7. Milchev R., G. Milchev. 2018. „ICT in the process offormation and development of convergence technologies“, Journalof Science, Enginering&Education, vol.3 issue 1, 54-62, ISSN 2534-8507.
8. Mishev, G. 1992. Quantification of multidimensional indicators. Scientific Collection of UNWE, Bulgaria, vol. 3, 3-31. (in Bulgarian)
9. Neykov N. K., E. Kitchoukov, P. Antov, V. Savov. 2019. Efficiency analysis of the Bulgarian forestry and forest-based industry: a dea approach. International Conference on Innovations and Science and Education. March 20-22. Prague.Vol 7: CBU International Conference Proceedings, 228-235, 2019.
10. Organisation for Economic Co-operation and Development, Joint Research Centre in Ispra. 2008. Handbook on Constructing Composite Indicators, Methodology and User Guide. France, 158 p.
11. Popova, I., M. Zinzova. 2015. Methodology for Determining Integrated Indicator for Competitiveness of Trade Chain, Internet Journal ‘Science Introduction’, 7, 1-11. (in Russian)
12. Stoenchev, N. 2016. The Quality of Life and Specialization of the Territory by Economic Activities in Bulgaria (Statistical Aspects). Publishing House ‘Intel Entrance’, Sofia, 122 p. (in Bulgarian).
13. Tsoklinova, M. 2015. Study of the components of competitiveness: productivity and generate economic growth, Eleventh International Scientific Conference of Young Scientists, The economy of Bulgaria and the European Union: Competitiveness and innovation, financial institution, Sofia, 471-478.
14. Tsoklinova, M., Impact of the Green Economy on the Level of Health Status of Population in Some EU Member States, 2020, Dialog- E-Journal of Tsenov Academy, ISSN: 1311-9206, Issue 2, p. 16.
15. Young, G., S. Pearce. 2013. A Beginner’s Guide to Factor Analysis. Focusing on Exploratory Factor Analysis. Tutorials in Quantitative Methods for Psychology, Vol. 9(2), 79-94. DOI: 10.20982/tqmp.09.2.p079

МНОГОМЕРНИ СТАТИСТИЧЕСКИ МЕТОДИ ЗА ИЗУЧАВАНЕ НА КОНКУРЕНТОСПОСОБНОСТТА НА ГОРСКОСТОПАНСКОТО ПРЕДПРИЯТИЕ

Константин Колев
Лесотехнически университет, София, България

Абстракт

Квантифицирането на конкурентоспособността на стопанските субекти, функциониращи в горското стопанство позволява да се вземат научно обосносновани управленски решения, чрез които да се повиши конкурентоспособността на равнище предприятие, което ще спомогне и за повишаване на конкурентоспособността на равнище сектор. В тази връзка целта на настоящата статия е да се сравнят два многомерни статистически метода – факторен анализ и линейно подреждане в многомерното пространство, като възможни инструменти за извличане на количествена оценка на конкурентоспособността на горскостопанското предприятие.

Key words: конкурентоспособност, факторен анализ, линейно подреждане в многомерното пространство, горско стопанство.
JEL: C40, C43.

MULTIDIMENSIONAL STATISTICAL METHODS FOR STUDY OF COMPETITIVENESS OF FORESTRY COMPANY

Address Contact
University of Forestry
Faculty “Business Management”
Blvd. “St. Kliment Ohridski “№10
Sofia 1797
Bulgaria

e-mail: konstantinklv@yahoo.com