MATHEMATICAL MODELS FOR DETERMINING THE MARKETING ACTIVITIES RATING OF STATES

Vasilij Novikov, Dzmitry Marushka
Belarusian State Economic University
Belarus

Elena Grinevitch
School of Business of Belarusian State University
Belarus

Annotation

The export and import indicators of interconnected states group are considered. The rating estimation model of states marketing activity is based on these indicators is offered. The technique is completely implemented by the use of software Mathcad. Some variants of the states' interaction with competing environment are considered. Programs listings implement algorithms for each variant are given. Methods: The calculation method is based on computation of import matrix eigenvector with its eigenvalue equal to unit. The states arranged set is lines and columns of an import matrix. Results: The matrix eigenvector is a calculation result. The eigenvector values in decreasing order are arranged. On this vector values the state rating is determined. Conclusions: The developed analysis algorithms of states' marketing activity can be used in planning of logistics interaction between the states. Also they can be used in priorities of export activity determining for each separate state.

Key words: *import, export, marketing, the state, an interstate turnover, a rating, a matrix, a vector, a population, a system of equations, an eigenvalue, an eigenvector.*

Introduction

The task of rating the members of a collective system, including divergent relations of organizations and states, becomes relevant in connection with the development of HRM (Human resource management) technology [1].

Aspects of marketing activities based on mathematical criteria considered in the scientific papers [2-5].

A promising direction for quantifying the behavior of a collective system is the method for analyzing the matrix of pairwise comparisons [6–8]. The methodology described in this article can be considered as a special case of the analysis of such tasks in relation to international marketing.

In state marketing activity and international marketing a great value have parameters that could be measured. They can be used as an instrument of goods promoting at the international level [9–11]. Each measured parameter is represented in a digital form. In the ratio on the same parameter of other states it determines a competitiveness character in the selected countries group.

It is necessary to notice the usage of mathematical methods and models is actually both in the firm activity level and in the macroeconomic level. In macroeconomic it is actually in planning and in economic activities aspects analysis of separate regions and all country as a whole [12].

Results and discussion

The marketing activity indicators of states group can be calculated on mathematical model [13-16] with recalculation of outcomes per capita. The square matrix **A** and the vector population **Z** (million) are used as the model input data. Each i-th column of the matrix **A** represents the percentage ratio between an import volume and an interstate turnover. For example, for *i=2* the column

$$[0.4 \quad 0.2 \quad 0.1 \quad 0.3]^T$$

covers 4 states, and import of the 2nd state with the first state constitutes 40 %, the 2nd state with the 3rd state – 10 %, the 2nd state with the 4th state – 30 %, and the internal turnover of the 2nd state constitutes 20 %.

If a vector of the export activity income is defined as a vector **X** then for it equality is valid:

$$\mathbf{A \cdot X = X} \tag{1}$$

Really, if we take, for example the 2nd state for it we will receive equality:

$$a_{21}x_1 + a_{22}x_2 + \ldots\ldots + a_{2m}x_m = x_2 \tag{2}$$

As defined **A** the coefficient a_{21} represents the 1st state import from the 2nd state, but it is export of the 2nd state to the first state. Thus, the left part equality (2) represents the total export of the 2nd state which could be equal x_2 by vector **X** definition.

According to the matrix **A** eigenvalue definition:

$$\mathbf{A \cdot X = \lambda X} \tag{3}$$

and given the fact that the columns sum of the matrix **A** is always equal to unit we receive the matrix **A** eigenvalues will be equal 0 or 1. The equality (3) turns in (1) at $\lambda = 1$. Thus, the system (1) has the nontrivial decision being the matrix **A** eigenvector at its eigenvalue $\lambda = 1$. The received eigenvector **X** represents the proportions of the states balanced budget. The vector **Y** values

$$y_i = x_i/z_i$$

represent the proportions of the states' marketing activity. If as base to take the maximum value of the vector **Y**, and the vector **Y** is renormalized on this value then all values y_i will be in a range from 0 to 1. Value y_i=1 corresponds to the state with the maximum marketing activity.

The software Mathcad solution for 5 states with arbitrarily taken the matrix **A** and the vector **Z** is presented:

$$\mathrm{ORIGIN} := 1$$

$$A := \begin{pmatrix} 0.2 & 0.1 & 0.1 & 0.3 & 0 \\ 0.4 & 0.2 & 0.4 & 0.1 & 0.3 \\ 0.3 & 0.3 & 0 & 0.2 & 0.2 \\ 0.1 & 0.2 & 0.3 & 0.3 & 0.1 \\ 0 & 0.2 & 0.2 & 0.1 & 0.4 \end{pmatrix} \qquad Z := \begin{pmatrix} 1.5 \\ 1.3 \\ 0.9 \\ 0.8 \\ 1.1 \end{pmatrix} \qquad m := \mathrm{cols}(A)$$

$$X := \mathrm{eigenvec}(A, 1) \qquad Y := \overrightarrow{\frac{X}{Z}} \qquad C := \max(Y)$$

$$i := 1..m \qquad Y_i := \frac{Y_i}{C} \qquad Y = \begin{pmatrix} 0.349 \\ 0.785 \\ 0.854 \\ 1 \\ 0.663 \end{pmatrix}$$

Model [3] shortage is the impossibility to calculate marketing activity of the states closed group. The matrix **A** in this model is specified so that no matter how many states we have not taken all of states of the world will be included in it on a chain. But the data on import of all countries of the world receive almost impossible.

We modify model (3) so that it was possible to consider only the closed group of the countries consisting from *m* of countries. On the formula (3) we will specify the matrix **A** column as the percentage ratio of the import of these *m* countries. An additional *m+1* element of this column will contain given country import to all remaining countries which are not entering in these *m* countries.

Under this definition the sum of the matrix **A** column will be equal 1 also. We add *(m+1)*-th column of the matrix **A** for export accounting. For the *i-th* country from *m* countries group we specify export $b_{i,\, m+1}$ from this country to all countries, not entering into *m* countries group. This column values we present in absolute units. Only for the *(m+1)*-th column of the matrix **A** it is impossible to set an internal trade turnover $b_{m+1,\, m+1}$ of the countries which are not entering into *m* countries group. The coefficient $b_{m+1,\, m+1}$ gets a value of 0 because we are not interested in total marketing activity of these countries.

We receive the column $a_{i,\ m+1}$ values from $b_{i,\ m+1}$ renormalized *it*:

$$a_{i,m+1} = \frac{b_{i,m+1}}{\sum\limits_j b_{j,m+1}}$$

After such the matrix **A** definition we receive the equations system (1) in which x_i (*i=1 … m)* determines balanced budget of *m* countries group.

The software Mathcad solution for the closed group of 4 states is presented below. The matrix **A** and the vector **Z** have arbitrary values.

$$ORIGIN := 1$$

$$A := \begin{pmatrix} 0.2 & 0.1 & 0.1 & 0.3 & 0 \\ 0.4 & 0.2 & 0.4 & 0.1 & 0.3 \\ 0.3 & 0.3 & 0 & 0.2 & 0.2 \\ 0.1 & 0.2 & 0.3 & 0.3 & 0.1 \\ 0 & 0.2 & 0.2 & 0.1 & 0 \end{pmatrix} \qquad Z := \begin{pmatrix} 1.5 \\ 1.3 \\ 0.9 \\ 0.8 \\ 1.1 \end{pmatrix} \qquad m := cols(A)$$

$$i := 1..m-1 \qquad C := \sum_{j=1}^{m} A_{j,m} \qquad A_{i,m} := \frac{A_{i,m}}{C} \tag{4}$$

$$X := eigenvec(A, 1) \qquad Y := \overrightarrow{\frac{X}{Z}} \qquad YY_i := Y_i \qquad C := max(YY)$$

$$\alpha_i := \frac{YY_i}{C} \qquad \alpha = \begin{pmatrix} 0.349 \\ 0.785 \\ 0.854 \\ 1 \end{pmatrix}$$

The received vector **Y** values describe marketing activity of *m* countries group in competing environment of all remaining countries.

The reduced model allows receiving coefficients y_i of marketing activity of the state taking into account an internal trade turnover. The marketing activity without an internal trade turnover is interesting for the complete analysis. The international marketing activity can be calculated, if the internal trade turnover is ignored in the matrix **A**. The coefficient $a_{ii}=0$ gets a value of 0. The software Mathcad solution of such task is presented below:

$$ORIGIN := 1$$

$$A := \begin{pmatrix} 0 & 0.1 & 0.1 & 0.3 & 0 \\ 0.4 & 0 & 0.4 & 0.1 & 0.3 \\ 0.3 & 0.3 & 0 & 0.2 & 0.2 \\ 0.1 & 0.2 & 0.3 & 0 & 0.1 \\ 0 & 0.2 & 0.2 & 0.1 & 0 \end{pmatrix} \qquad Z := \begin{pmatrix} 1.5 \\ 1.3 \\ 0.9 \\ 0.8 \\ 1.1 \end{pmatrix} \qquad m := cols(A)$$

$$i := 1..m \qquad C_i := \sum_{j=1}^{m} A_{j,i} \qquad j := 1..m \qquad A_{i,j} := \frac{A_{i,j}}{C_j}$$

$$X := eigenvec(A, 1) \qquad Y := \overrightarrow{\frac{X}{Z}} \qquad i := 1..m-1 \qquad YY_i := Y_i \tag{5}$$

$$C := max(YY) \qquad \beta_i := \frac{YY_i}{C} \qquad \beta = \begin{pmatrix} 0.327 \\ 0.735 \\ 1 \\ 0.819 \end{pmatrix}$$

In above example as the matrix **A** are taken the same values when calculation of coefficients taking into account internal marketing. The comparative analysis of the resulting y_i on this and previous models allows specifying for the *i-th* state what marketing in it - interior or international - dominates. So, for example, in our examples for the *i=3* states it has turned out that *α3=0.854* taking into account internal marketing and *β3=1* only at the expense of international marketing. As *β2* is larger than *α2* in the third state the external economic marketing activity dominates but not interstate activity.

The reduced two models give not a complete picture of marketing activity of the state as very often the state is a part of the union from the several states. In this context important information is the estimation of marketing activity in the union.

Let's assume this is the group of *m* states representing some economic system. In the columns of the matrix **A** as before we specify import of the country to other countries. As the column includes a closed set of the countries the sum of its elements will be equal *bi* <1. To a value 1 b_i is supplemented by the countries which are not entering into the union. As export and import should be balanced for the closed group of *m* countries the equations system is fair:

$$\sum_{j=1}^{m} a_{ij} x_j = b_i x_i , i = 1..m \tag{6}$$

In the equations system (6) we make a change of variables:

$y_i = b_i x_i$

and after a designation $a_{ij} = a_{ij}/b_j$ we receive the system (1) at which as before the columns sum of a matrix **A** is equal 1. The software Mathcad solution for five states with similar data models (4, 5) is given below:

$$ORIGIN := 1$$

$$A := \begin{pmatrix} 0.2 & 0.1 & 0.1 & 0.3 \\ 0.4 & 0.2 & 0.4 & 0.1 \\ 0.3 & 0.3 & 0 & 0.2 \\ 0.1 & 0.2 & 0.3 & 0.3 \end{pmatrix} \qquad Z := \begin{pmatrix} 1.5 \\ 1.3 \\ 0.9 \\ 0.8 \end{pmatrix} \qquad m := cols(A) \qquad i := 1..m$$

$$b_i := \sum_{j=1}^{m} A_{j,i} \qquad j := 1..m \qquad A_{i,j} := \frac{A_{i,j}}{b_j}$$

$$X := eigenvec(A, 1) \qquad X_j := \frac{X_j}{b_j \cdot Z_j} \qquad d := max(X) \tag{7}$$

$$\gamma_j := \frac{X_j}{d} \qquad \gamma = \begin{pmatrix} 0.346 \\ 0.762 \\ 0.852 \\ 1 \end{pmatrix}$$

The comparative analysis *α2=0.785* from model (4) and *γ2=0.762* from model (7) shows that marketing activity of the 2nd state in the union of five countries is less effective.

By analogy to model (5) for a closed set of *m* countries it is possible to specify marketing activity without an interstate turnover. For this purpose after recalculation

$A_{ij} = A_{ij}/b_i$

in model (7) the diagonal elements of a matrix **A** must be set to zero values.

The software Mathcad solution is given below

$$ORIGIN := 1$$

$$A := \begin{pmatrix} 0.2 & 0.1 & 0.1 & 0.3 \\ 0.4 & 0.2 & 0.4 & 0.1 \\ 0.3 & 0.3 & 0 & 0.2 \\ 0.1 & 0.2 & 0.3 & 0.3 \end{pmatrix} \qquad Z := \begin{pmatrix} 1.5 \\ 1.3 \\ 0.9 \\ 0.8 \end{pmatrix} \qquad m := cols(A) \qquad i := 1..m$$

$$b_i := \sum_{j=1}^{m} A_{j,i} \qquad j := 1..m \qquad A_{i,j} := \frac{A_{i,j}}{b_j} \qquad A_{i,i} := 0$$

$$C_i := \sum_{j=1}^{m} A_{j,i} \qquad A_{i,j} := \frac{A_{i,j}}{C_j} \qquad X := eigenvec(A, 1) \tag{8}$$

$$X_j := \frac{X_j}{b_j \cdot Z_j} \qquad d := max(X) \qquad \delta_j := \frac{X_j}{d} \qquad \delta = \begin{pmatrix} 0.325 \\ 0.671 \\ 1 \\ 0.783 \end{pmatrix}$$

If to calculate marketing activity on the models (4, 5, 7, 8) for the same countries the comparative analysis *α, β, γ, δ* for separately taken country gives a chance to reveal the weakest of marketing activity of the state. If α_i it will appear the least value it means that in the state the interstate marketing activity connected with the competing environment of the union of *m* countries is insufficient. If it will appear the least β_i it means that the international marketing activity concerning the competing union *of m* countries is insufficient. If the least γ_i it means marketing activity connected with the union of the countries is insufficient. If it will appear the least δ_i it means international marketing activity among *m* countries entering into the union is insufficient.

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