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A Contribution to the Application of the Structural Analysis Method in Entrepreneurial Practice

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Abstract**—**Quantitative methods of economic decision-making as the methodological base of the so called operational research represent an important set of tools for managing complex economic systems,both at the microeconomic level and on the macroeconomic scale. Mathematical models of controlled and controlling processes allow, by means of artificial experiments, obtaining information foroptimalor optimum approaching managerial decision-making.The quantitative methods of economic decision-making usually include a methodology known as structural analysis -an analysisof interdisciplinary production-consumption relations.

Keywords**—**economic decision-making, mathematical methods, structuralanalysis,technical coefficient

I. Introduction

At present, themethods ofoperational research represent a set of tools forthe management of complexeconomic systems, bothat the microeconomiclevel andon the macroeconomicscale.According toZimola[1], the operational research provides and opportunity toimprove the economicdecision-making, particularly in terms of speedandcompetency, using quantitativemethods.That is why the mathematicalmodelling is more and more often used as an integralpart ofeconomic theory andeconomic practice.

II. Structural Analysis

Each production - consumption system (national economy, department, field, branch, and company) consists of certain elements (fields, branches, technologies, products), among which there are links such as supplier-customer relations. Any change in one element may show itself in those elements which the given element is directly or indirectly linked with. When examining the conditions of economic balance of the production - consumer systems, during analysis and operational reflection of changes in production-consumption relations of the production - consumer systems we can bear on an existing set of general theoretical knowledge of mathematical modelling and analysis of production-consumption links, usually known as *the structural analysis*[1].

The structural models as products of this methodology display endogenous and exogenous production-consumption relations of the production-consumption system in various conditions. According to Římánek [2], the structural model can be understood as an instrument enabling us to capture the mutual relations of the individual elements of the economic system and the links of these elements to the surrounding environment. It represents certain quantitative way of displaying the production - consumption processes, where the creation and utilization of production is captured not only as a whole, but in its structure as well.

The presumption of equality between the resources and needs of each element of the production - consumption system is an essential feature of the structural model. The structural model represents a system of balances which describe the resources and also the distribution of consumptions of all the model components (elements) of the production – consumption system in a single complex of equations. From the mathematical apparatus, the structural models use mainly linear algebra. The mathematical essence of the basic types of the structural models is represented by a set of linearly independent equations. The number of linearly independent equations depends on the type of the model, for example in case of Leontief´s and Pichler´s type; it equals the number of variables, so the system of equations has a clear solution (if a solution exists at all).

Using the mathematically defined models balance of factory-consumer relations are prevalent and the historically oldest models in the economy and these had originally view relationships in the reproductive process at the macroeconomic level [3],[4] gradually expanded to the level of business entities and has been the one of the important tools of economic governance. Professional literature gives numerous examples dedicated to real applications, for ex. [5], [6].

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[1]There are various names used in various literary sources, for ex. input-output models, models of relations among the branches, balance models, Leontief´s models or matrix planning models

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III. Leontief´s Models

Wassily W. Leontief is generally regarded as the founder of the structural analysis. The basic methods W. W. Leontief called „input – output analysis" are explained in his book „The Structure of American Economy, 1919-1929[3].

Leontief´s static models are the most common representatives of the structural models. The first model assembled by Leontief was the so called closed static model used for analysis of the structure of the U.S. economy in the years 1919 – 1929[3]. The closed model does no include any autonomous input or output; all variables are fully interconnected by their feedbacks. On the other hand, the models where one group of branches acts as producers and consumers at the same time, while the second group acts only as consumers, are open models. As Leontief himself[4]states, when justifying the transition from a closed to an open model, the open model is more useful in terms of active economic policy. In an open model, we can analyze not only the existing situation, but if there are the technical coefficients, we can also calculate the extent of the overall production of the individual branches to any specified size and structure of the final production. The application of these models or variations has been extensively used in studies spanning a broad variety of disciplines.

The *static open Leontief´s structural model* is clearly schematically illustrated by a staggered table that graphically illustrates the flows of goods, raw materials, energies and other production factors, both within any random production and consumption system such as a company, and between them and the surrounding environment in the period under consideration , Fig. 1.

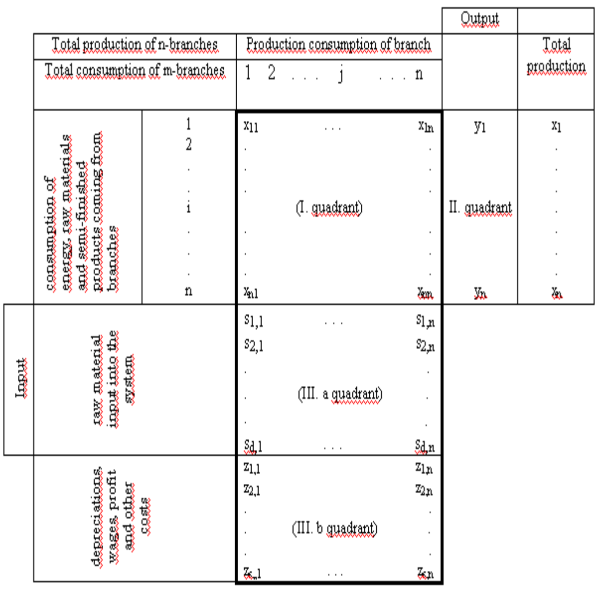

Fig. 1 Basic scheme of the staggered table
Revised from: [7]

As stated by Janovská [8] if we call the products with varying degrees of aggregation branches, then the staggered table for any random production - consumer system with n-branches can be divided into several "fields", known as "quadrants".

Thefirst "quadrant" of the staggered table shows the consumption of production - the flow of materials, intermediate products and energies between the production branches.

The second "quadrant" represents the so called final consumption (in practice, it means especially sales - sales of products of the given branch, but also its "non-productive" consumption in the system).

The third a (III.a)"quadrant" captures the material - energy input into the system (in practice, it means the consumption of the purchased raw materials, materials and energies).

The third b (III.b) "quadrant" shows the newly created value (part of the value of production created by material inputs processing; in practice, they are depreciations, labour costs, the profit from sales of production). [8]

The schematic staggered table can be used to derive a basic set of equations for the production-consumption system with n-manufacturing branches and k-supplying branches - a system of balance (distribution) equations:

system (n + k) of distribution equations, showing the presumption of economic balance of the system:

$$x_i = \sum_{j=1}^{n} x_{ij} + y_i \qquad (1)$$

when i = 1,2,…n j = 1,2,… n

$$s_d = \sum_{j=1}^{n} s_{dj} \qquad (2)$$

when d = 1,2,…k

where:

x_i …total production volume of the i- th branch

x_{ij}…..consumption of production of the i-th branch in the j-th branch of the given production-consumption system

y_i …. total „final consumption" of production of the i-th branch

s_d ….total consumption of production of the d-th supplying branch

$s_{d,j}$ …consumption of production of the d-th supplying branch in the j-th branch

As stated by Vepřek [9]simplifying presumption of linearity between the manufacturing consumption of production of the i-th branch in the j-th branch x_{ij} and the volume of production of the j-th branch $x_j$expresses the relation that is known as *theLeontief´s cost function*:

$$x_{ij} = a_{ij} x_j \qquad (3)$$

where
a_{ij} ….*coefficient of direct specific consumptionof production* of the i – th branch in the j –th branch; expresses production volume of the i-th branch necessary to manufacture a production unit of the j – th branch
x_{ij}…..consumption of production of the i-th branch in the j-th branch of the given production-consumption system
x_j….the volume of production of the j-th branch

Should we introduce the expression (3) into the system of distribution equations (1), (2), then their matrix expression is

$$\underline{x} = \underline{A}\underline{x} + \underline{y} \quad (4)$$

$$\underline{s} = \underline{C}\underline{x} \quad (5)$$

where
$\underline{x}$ ……vector of total production volume xi; i = 1,2,…n
$\underline{y}$ ……vector of final consumption of production – sales of production yi ; i = 1,2,…n
$\underline{A}$ (n,n) ..matrix of direct consumption coefficients aij ; i,j = 1,2,…n
$\underline{s}$ ……vector of total consumption of production of supplying branches sd d = 1,2……k
$\underline{C}$ (k,n) ..matrix of direct consumption coefficients sd,j ; d = 1,2……k, j = 1,2,…n

After modification:

$$\underline{y} = \underline{(E - A)}\underline{x} \quad (6)$$

$$\underline{x} = \underline{(E - A)}^{-1} * \underline{y} \quad (7)$$

$$\underline{(E - A)}^{-1} = \underline{B} \quad \rightarrow \quad \underline{x} = \underline{B} * \underline{y} \quad (8)$$

$$\underline{s} = \underline{C} * \underline{B} * \underline{y} \quad (9)$$

$\underline{E}$ ………type unit matrix /n,n/
$\underline{B}$ (n,n) ..*matrix of coefficients of complex* (direct and indirect) *consumption of production* of the i-th branch in the j-th branch

The elements b_{ij} of matrix B represent the total amount of production of the i-th branch needed to manufacture a production unit of the j-th branch intended for final consumption - sales.

The indirect consumption is a mediated consumption, given by the fact that the relevant j-th branch production needs include not only the given i-th branch but also the production of other branches that also consume the production of the relevant i-th branch.

IV. TECHNICAL COEFFICIENT - PROBLEMS OF ITS CONSTRUCTION

The basic and pivotal presumption in construction of the Leontief´s static models is the proportional relationship between production and consumption $x_{ij} = a_{ij} x_j$.

It means that the *coefficient a_{ij}* expresses what amount of product of the i-th branch is necessary in the given system to manufacture a production unit of the j-th branch, and that is why it represents a fundamental quantity of the structural model. The relevance it is determined with decides about the demonstrative power of the structural analysis.

Depending on whether the starting balance (staggered table) has been prepared using natural or value expression, the coefficients a_{ij} have the matching character.

Quantification of flows between the individual branches in *natural units* (for ex. tons, MJ, ...) makes up the basis of the *natural structural analysis*. This analysis can also be supplemented by information about the flows between the economic sectors and the environment, such as production of waste [10], consumption of resources [11], utilization of land [21].

As stated by Weinzettel in [13], this type of analysis is too demanding for data, which is why it is not applied very often.

If we start from the balance in natural units, the value of coefficient a_{ij} is primarily determined by the production technology and that is why the coefficient a_{ij} is known as *the technical coefficient.* The technical coefficients have, in this case, the nature of a consumption standard which is characteristic for the given production technology. As stated by Vepřek [9], when using the natural units, it is a disadvantage that the technical coefficients generally do not meet the usually sufficient condition of enabling the economic interpretation of the matrix elements $[E\text{-}Al]^{-1}$, i.e. that $a_{ij} \leq 1$ (i,j = 1, ... n), and therefore it is required that the character of the elements of the inversion matrix must be closely examined in such cases.

The value expression of the coefficient a_{ij} is more common especially at higher management levels. In this case, the elements a_{ij} of matrix A express the consumption of production of the i-th branch required to manufacture a production unit of the j - th branch in *monetary units*. The basis of *the monetary structural analysis* is the quantification of the flows between the individual branches in monetary units (for ex.: Kč, EUR, etc..).

When using the monetary units, there is a problem of uniform appreciation of products. If it is impossible to keep the principle of uniform appreciation, it leads to distortion of material links displayed in a model and it reduces its accuracy, or even puts its usability in jeopardy. When using the monetary units, the technical coefficients usually meet the sufficient condition for economic interpretation ability of the matrix elements $[E\text{-}Al]^{-1}$, i.e. that $a_{ij} \leq 1$ (i,j = 1, ... n).

As stated by Weinzettel in [13], when the monetary units are replaced by natural units for selected products, we are talking about the so-called *hybridanalysis*. The outcomes of this kind of analysis are directly the physical flows of the selected materials (for ex. tons of coal, tons of oil, and others). This method is described in more details in the literature [14],[15], and it was later used in the literature [16].

Habr [17] claims that the validity of the hypothesis of direct proportionality between production and production consumption *should be limited in time*. The technical coefficients can not be considered as constant in longer-term; they are gradually adjusting to reflect the prices of the inputs and they reflect the new technologies. Experience shows that in the national economy as a whole, the changes do not usually occur in steps, but they are gradual. *The effect of the introduction of the new technologies* into operation depends not only on the technical parameters but also on the relative importance in the production branch in question. If the new technology takes up only a small part of the capacity of the given branch, then its effect on the technical coefficients can usually be neglected, otherwise it is necessary to examine the technical coefficients.

Janovská [8] points out that this assumption (a direct proportion between production and production consumption) does not describe the reality accurately enough - the rate at which it approximates to reality is different for different branches and may not be acceptable for each type of the production-consumption system or for each type of production. It can be an expression of long-term production experience. When the same manufacturing procedure, and the same technology of production is used to manufacture a certain product, the consumption of used raw materials, energies, materials and semi-finished products depends above all on the size of production of the given product and is only marginally influenced by other factors.

In cases where structural analysis is used as a cognitive instrument of detailed relations in economic groups, *the heterogeneity of the individual branches* is a major factor that has significant impact on the technical coefficients. The technical coefficients are in fact average values (weighted by the value of production) influenced by structural changes. It is obvious that the size of the technical coefficients is also affected by the degree of aggregation of the individual branches. As Rojíček claims [18], the more homogeneous the individual branches are, the more stable the technical coefficients will be, because the lower the possibility of structural changes is.

The question of *defining the branch* is one of the most important issues which the informative value not only of the inter-branch balance, but also the mathematical models derived on its basis depend on. In the designed tables, the number of branches practically varies from several tens to several hundreds, while, as noted by Habr [17], the stability of the technical coefficients requires the individual branches to be as homogenous as possible, i.e. the classification of branches should be as delicate as possible. However, too large number of branches is not only unsustainable in terms of data collection and their processing, but also in terms of their analysis. The balance matrices used in practice for the entire national economy tend to be large, where n may reach the value of hundreds or thousands. That is why further processing makes use of the aggregation principle that enables adjusting the entire balance to size which allows easier subsequent processing.

The changes of the technical coefficients are then essentially influenced by two circumstances:

- *changes in technology*
- *changes in the structure of a branch*

It means that the usefulness of construction of the structural model and the relevance of the provided information for the decision-making processes depend on the correct determination of the coefficients a_{ij} themselves as the technical coefficients or the consumption standards.

As already mentioned before, the basic presumption of the Leontief´s static models is the linearity of relations between the production consumption and the production of the individual branches. The inclusion of nonlinear dependencies (production and production consumption) is not so much interfering with the mathematical problems, but it is mainly the difficulty of construction of the nonlinear models, and the issue of feeding such a model with sufficiently accurate input data.

V. The Input Data - Suitable and Consistent Data

The solution of the issue of feeding the model withthe basic data- the acquisitionof *suitable andconsistent data* is of fundamental importance during the construction but, above all, in practical application of the structural models.Manymodelshave not seenany widerpractical usejust because this issue had beenunderestimated.According to Mikušová[19] the enterprise and government executives has revealed that one of the most frequently reported common disappointments is a lack of data integrity and system inability to produce useful information to support decision-making.

Duringthe assemblyof the structuralmodels ofthe production-consumption system, therewas a question howto obtain suchbasic data, to avoid the technicalcoefficientsbeingaffected(or to have them affectedas little as possible) by the method of the data collectingand processing.

There are a number of views of a quality dates[20]. In a simplified way it can be said that quality dates are as follows[21]:

- they are in harmony with company's strategic
- priorities and customers' priorities,
- they are appropriately chosen for company's
- operation as well as for work of individuals,
- it is easy to develop and adjust them,
- they can be quickly implemented,
- they are easily understandable,
- they lead to the improvement,
- they are not an inviolable thing,
- they are not left to exist forever.

Giventhat all thematrixmodels arerelativelyhighlysensitive to changesin the numerical values, it is importantfor the technicalcoefficients ofthe model to describe themodelledreality withutmost precision, because in case of matrixinversionoperations the inaccuraciescanexpandout of control. In his work[22], Rutrle indicates that experimentshave proved that 5% deviationin thematrixof direct consumptionmay cause upto 30% deviationin someelements of the inverse matrix,i.e.the matrix complex consumption coefficients.The issue of the matrix inversionis also described bySimonovits in his work [23]. It means that inextensivecomputationalworkeven smallerrors canaccumulateand they cansignificantlydebasethe results,even ifthe basichypotheses are accurate.

Obtaining relevant data, especially at company level is then the usual fundamentals problem arising during composition of the structural model.Workersoutside the company sphere in questionoftencome acrossbarrierswhen it comes toobtaining relevantdata,in particular withreference to a"trade secret".

The source ofknowledgemayalso come fromthe structuralmodelsbased on theuse of the availableretrospectivedataof a technical nature(capacity characteristics, consumer numbers)that arepublished andwidelyavailablefor example inannualreports and bulletins,and in many cases thesefiles ofaggregateddatado not change significantlyyear on year, and theycanform the basisfor establishingthe basicmatrix ofproduction and the consumerrelationsand, by means of a simplesoftware transformation, they can be usedto calculate thematrices of the so calledcoefficients ofcomplex (both direct and indirect)consumption.

VI. Conclusion

In conclusion, we can say thattheuse ofthe economic-mathematical methods inentrepreneurial practiceis completelyjustifiedand it givesthe opportunityto speed up, refineand improve the decision-makingprocesses ofmanagersand executivesof companies, butit should be notedthat the excessiveapplication of mathematics has a paradox tendencyofobscuring thereality.

As the Nobelprize winner in economicsW.Leontief himself writes, "*uncritical enthusiasm for mathematical formulation tends often to conceal the ephemeral substantive content of the argument behind the formidable front of algebraic signs"' (....) in noother field of empirical inquiry* [asin economics] *has so massive and sophisticated a statistical machinery been used with such indifferent results.(...) .. mostof these*[mathematical models] *are relegated to a stockpile without any practical application.* [2].[24]

As stated by a Czech economist and main macroeconomic strategist of ČSOB Sedláček [24], "mathematics is an incredibly powerful tool, but you must understand that the mathematical apparatus can never yield more than what you put into it. And if mathematics is the basic language of economics, then the economists must put into its formulas some economic content of their own, otherwise their theory becomes an empty exercise, when the after some mathematical "abracadabra" brings the desired result from the axiomatic presumptions."

In any case, the structural models represent *a compromise* between the pursuit for the most precise and the most comprehensive picture of the economic reality and the request for availability of adequate input data and parameters for the completion of the model. When using any structural model, it is necessary to keep in mind the limitations and simplifications it results from, and to take them into account when interpreting the outcomes acquired from a model.

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