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APPLICATION OF THE MATRIX METHOD IN ECONOMIC MODELING

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Abstract: *The matrix method for designing models is common and widely applied in various fields of economics. Matrix methods in economic modelling can generally be in a form of linear algebraic equations or equivalent representations. The process of defining certain assumptions and adopting the model is done by formulation. It includes breaking down the problem and defining the steps in which the problem will be solved. Matrix programming methods represent a class of optimization economic models because their goal is to find optimal solutions to problems. For a complex analysis of the economic structure and interconnection of individual parts of the economy, flows, and reproduction processes, intersectoral (input-output) tables provide the necessary statistical and informational basis. The cross-sector matrix (input-output) models allow a deeper insight into the structure and interdependence of individual economic processes. In this context, the main goal of this paper is to show the importance of applying the matrix method in economic science because its correct application can reduce many ambiguities, both in economic theory and in practice.*

Keywords: *business management, activity classification, cross-sectoral tables, national accounts.*

JEL classification: *C67*

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PRIMENA MATRIČNE METODE U EKONOMSKOM MODELIRANJU

Sažetak: *U današnjem svetu je razvoj matrične metode za projektovanje modela u različitim oblastima ekonomskih nauka veoma zastupljen i široko primenjen. Matrične metode u ekonomskom modeliranju se uglavnom mogu prikazati u obliku linearnih algebarskih jednačina ili ekvivalentnim prikazima. Proces definisanja odeđenih pretpostavki i usvajanja modela obavlja se formulacijom i obuhvata određivanje stepena raščlanjivanja problema i definisanje koraka u kojima će se problem rešavati. Matrične metode programiranja predstavljaju klasu optimizacionih ekonomskih modela, jer im je cilj pronalaženje optimalnih rešenja problema. Za kompleksnu analizu ekonomske strukture i međusobne povezanosti pojedinih delova privrede, tokova i procesa reprodukcije, intersektorske (input – output) tabele daju neophodnu statističku i informatičku osnovu. Na ovoj statističko-informacionoj osnovi počiva konstrukcija i praktična primena međusektorskih matričnih (input-output) modela, koji omogućavaju dublji uvid u strukturu i međuzavisnost pojedinih privrednih procesa. U tom kontekstu, osnovni cilj ovog rada je da prikaže značaj primene matrične metode u ekonomskoj nauci, jer se njihovom pravilnom primenom mogu smanjiti mnoge nejasnoće, kako u ekonomskoj teoriji, tako i u praksi.*

Ključne reči: *poslovno upravljanje, klasifikacija delatnosti, međusektorske tabele, nacionalni računi*

1. INTRODUCTION

Economic systems belong to the group of social systems and, by their nature, are the most complex of known systems in general. Management at all levels of an economic system encounters a series of problems, the root cause of which is an insufficient understanding of the established relationships between market entities, their mutual connection and interactions. Bearing in mind the above, decisions are often implemented that are far from the mathematical-technical and economic-social optimum at a given moment, which ultimately leads to a slower dynamic of economic development, a reduction in profit and a deviation from the trajectory of optimality (Pantić, 2021). The outcome are disproportions in the national economy and structural mismatch in the allocation of production factors at all levels, with all the accompanying consequences and problems.

In the case of solving complex economic problems, when business goals can be quantitatively expressed, various quantitative methods and models are very effectively used to make optimal business decisions (Klincov, 2022). This is why, in recent decades, more and more attention has been paid to examining the

possibility of applying and developing different quantitative analysis models to achieve successful business management.

Different models of quantitative analysis are used for the needs of business management in situations where some complex problems need to be solved, which can be quantitatively expressed and successfully presented with selected mathematical and statistical relations.

2. INPUT-OUTPUT TABLES

The input-output table is an account within the social accounts that shows part of current commodity transactions with intermediate products (reproductive consumption) (Miljković, 2001). The analysis of intersectoral relations in its modern form originates from W. Leontief. In 1931, Leontief began empirical research into the intersectoral connection of the American economy in 1919 and 1929. He published the first results of this research in 1936 in the article "Quantitative Input and Output Relations in the Economic System of the United States". A more complete version of this study was published in 1941 in the book "The Structure of American Economy, 1919-1929". Leontief continued this research from 1944 – 1946 and formulated and applied an open static intersectoral model. These works were republished in 1951 in the fourth part of the expanded edition of the book mentioned above, which includes an analysis of the structure of the American economy for 1939.

Each final product goes through many technological stages and represents the result of the entire technological process. The final product is not produced to test the importance and functioning of the technology but for sales and maximum profit. In conditions of intense market competition, every entrepreneur takes a part of the technological chain for himself and specializes in it. The higher the specialization, the lower the costs and the higher the earnings. Thus, the economic motive of profit revives the entire technological process and simultaneously organizationally divides that whole into a multitude of independent participants in the market.

The task of input-output tables is to statistically record all purchases and sales among production sectors and present them in a form that will enable their use when creating structural models to analyze structural interdependencies in the economy.

In the cross-sectoral table, the production macro system of the national (or regional) economy is divided (disaggregated) into specialized production sectors. Theoretically, the number of sectors in the table can be the same as the number of products. The cross-sectoral analysis assumes that one product is produced only in one sector. However, such a table, with several thousand

sectors, would be too cumbersome, impractical and therefore useless. Therefore, similar products are included in one sector. That process, the process of uniting and gathering similar products into one sector, is called aggregation.

Aggregation is one of the critical problems and its solution depends on the utility value of many instruments of economic analysis (Šoškić, 2022). What is the problem of aggregation in cross-sectional tables? This problem is defined as follows: how to get a sector in which (Rakić, Adamović, & Špiler, 2021):

1. each company produces only one product (same input)
2. each company in that sector applies the same production, i.e., technological procedure (same input structure).

The activity classification is similar to the chart of accounts, as it contains several levels of data collection. Although there is an official classification of activities, more is needed for the simple formation of a sector. The correct construction of intersectoral balances and the discovery of intersectoral connections and their quantification are possible only if the sectors are homogeneous. The number of sectors should be such that it enables the quantification of the essential interdependencies in the economy that we want to look at. Therefore, the purpose of the table is to determine the number of sectors (Obradović, Dmitrović, & Mitić, 2021).

A table with eight sectors is used to view global intersectoral relations and connections in our economy, while a table with 98 sectors is used to view more detailed connections (Savić & Bonić, 2022). In practice, cross-sector models are applied from just a few to 3,250 sectors, as in the table of cross-sector relations for the Norwegian economy in 1966 (Spencer, 2016).

The criteria for aggregating sectors that can be classified into three groups:

1. Mathematical,
2. Technological systematization of production activities and
3. Aggregation according to technical characteristics.

In the group of mathematical criteria the minimum distance criterion formulated by Fisher is used as a measure (Anderson, 1996).

$$\min. c = S\ Cr$$

$$Cr = S(aik - ail)2$$

The second group of criteria starts from the characteristics of technological processes. For example, the classification of all products in all branches of the economy is carried out through 4 basic operations:

- obtaining raw materials,
- cleaning raw materials, which includes operations using which necessary changes are made to products for further production,
- use of those materials in the creation of some semi-finished products,
- manufacturing and production of final products.

The limitation of this criterion is that some products go through twenty or more production processes, so it is not easy to aggregate them.

The third group starts from the technical characteristics of the products that are classified and relies on the previous systematization of technological processes (Šegrt, 2021). In this sense, we can distinguish the following forms of aggregation:

- Vertical aggregation: when one industry completely absorbs the production of another industry, and the production function does not allow substitution, those two industries can be combined.
- Horizontal aggregation of production stages: products in the same production stage are grouped together.

In the current international System of National Accounts (SNA) dating from 2008, unlike earlier versions that will be discussed later, the presentation of the mutual relations of market participants has been significantly changed and consists of two interconnected tables, namely: table of available goods and services and their uses (supply and use table) and symmetric input-output table.

3. TABLE OF AVAILABLE GOODS AND SERVICES

The table of deliveries and the table of uses are basic tables for analyzing the mutual relations of economic activities and are the basis for balancing the flow of deliveries and the use of goods and services. They also show data on production expenditures by activity for factors of production - labour and fixed capital (Savić, Mihajlović, & Kostić, 2022). Table 1 shows the total available goods and services originating from domestic production or imports. The rows show the values of different types of products according to product classification. The columns first show the production of corresponding products and services by industry. The last column shows how many of the available products in the domestic economy were imported and of what type.

Production volumes are shown at basic production prices. Taxes and product subsidies are shown by product type to obtain the total supply of each product type at purchase prices.

Table 1

Abbreviated table of deliveries of goods and services for three sectors of production

Goods and services	Total deliveries at purchase prices	Taxes minus subsidies on products	Production by activities				Export of goods and services
			Agriculture	Industry	Services	Total at basic	
Agricultural products	128	2	87	-	2	89	37
Industry products	2.685	111	2	2.112	115	2.229	345
Services	1.380	20	-	11	1.275	1.286	74
Acquisitions of residents abroad	43	-	-	-	-	-	49
Total deliveries at purchase prices	4.236	133	89	2.123	1.392	3.609	499

Note. Authors' calculation based on https://publikacije.stat.gov.rs/G2023/PdfE/G20233004.pdf

The use table (Table 2) provides data on available goods and services and the structure of costs by activity. The table has three quadrants. The intermediate consumption quadrant shows the consumption at purchase prices in columns by activities and in rows by products. The final use quadrant shows exports, expenditures for final consumption and gross investments at purchase prices in the columns. All these amounts are broken down in rows by product. For example, how much of the industrial product was used for final consumption, gross investments or exports? Moreover, finally, the value-added use quadrant shows the other costs in production, except for intermediate consumption. The forms of use of surplus value are compensation for employees, taxes, consumption of fixed capital, income, and operating surplus.

Table 2

Shortened table of uses of goods and services

Goods and services	Total uses at purchase prices	Taxes minus subsidies	Intermediate consumption				Export of goods and services	Expenditures for final consumption	Gross investments
			Agriculture	Industry	Services	Total by activities			
Agriculture products	128		3	71	14	88	7	30	3
Industry products	2.685		36	969	246	1.251	435	611	388
Services	1.380		8	218	318	544	69	744	23
Acquisitions of residents abroad	43							43	
Procurement of residents in the country						1.883	29	-29	
Total uses at purchase prices	4.236		47	1.258	578	1.721	540	1.399	414
Gross value added	1.854	133	42	865	814	762			
Compensation of employees	762		9	407	346	58			
Tax minus subsidies on production and imports	191	133	-2	49	11	432			
Mixed net income	432		14	262	156	247			
Operating net surplus	247		10	55	182	222			
Consumption of fixed capital	222		11	92	119	442			
Mixed gross income	442		17	264	161	459			
Operating gross surplus	459		18	145	296	3.604			
TOTAL	3.604		89	2.123	1.392				

Note. Authors' calculation based on World Bank database.

4. SYMMETRIC INPUT-OUTPUT TABLE

The International System of National Accounts (SNA) from 2008 recommends creating a symmetrical input-output table. It is symmetrical because the table has the same number of rows and columns. The table can be in the form of product-by-product or industry-by-industry. The product-product table shows which products were used in the production of certain products, and the industry-by-industry table shows which activity uses the products of certain activities.

However, the table in its final form is not square. Only the most important part of the table showing deliveries and uses of intermediate products is square-shaped. The table is extended to the right to show deliveries of certain products to final consumers and down to show the costs of employee wages, taxes, operating surplus and consumption of fixed capital. Therefore, the table looks like a rectangular cross, in which the cross is over the square part, which shows the consumption of intermediate products. International organizations recommend creating product-by-product tables because that form provides the best data for economic analysis.

The product-by-product table consists of three quadrants:

1. The upper left, I quadrant, contains data on intermediate consumption; rows show products, and columns activities.
2. The upper right, II quadrant, shows the forms of final use.
3. The lower left, III quadrant, shows the use of gross added value by its basic components.

The intersectoral table is divided into three organically connected quadrants:

1. The first quadrant of the table shows how much each production sector contributes to final demand (personal consumption, general consumption, investments and exports). One of the shortcomings is that the first quadrant does not provide information on who the consumer is. It only provides information on the origin, i.e., information about the producer (sector) in which the goods were produced.
2. The second quadrant is the most important part of the cross-sectoral table. It shows reproduction consumption, i.e., the giving and receiving of one sector to another, i.e., intersectoral dependencies within production systems in the economy.

3. The third quadrant shows added value (depreciation, personal income and accumulation) as well as the value of imports.

In order for the data from the intersectoral table to be used in the construction of intersectoral models, it must meet the following conditions:

- The second quadrant of the table must be a square matrix, i.e., must have the same number of rows and columns.
- The sum of rows and columns in the second quadrant of the table must be equal, which means that the sum of all sector purchases and their sales is equal.
- The global values of the first and third quadrants must be equal. Equality arises from the balance of commodity and money flows.

The intersectoral table shows the economic balance achieved in one period, while distributed and available funds are equal. Transport costs and trade margins, which make up the difference between producer prices and purchase prices, are included in the ranks of the transport and trade sector as the value of their services performed for individual consumers (Krunić, Stojmenović, & Kukolj, 2023). In this way, the total amounts of material expenditures of individual production sectors are expressed in purchase prices.

It is the same with the presentation of components of final consumption. Products of individual sectors delivered to a specific component of final consumption are shown in producer prices, and transport and trade services are shown in separate rows as transport and trade deliveries. Therefore, each component of final consumption is presented in purchase prices. This fact should be considered when comparing the data from the intersectoral table with the corresponding data from other statistical sources, which can be presented in different values.

In order to fit foreign trade flows into balances of domestic production and consumption flows, the value of imports and exports is shown in internal prices, which means that customs duties and tariffs are included in the value of imported products.

Table 3. shows import flows separately from domestic flows. Namely, all imported products are classified by sector of origin in separate rows of the table and distributed to the reproduction consumption of individual sectors and components of final consumption. This way, a matrix of import flows and a separate matrix of domestic flows are obtained (Dowling, 2005). This form of cross-sectoral table enables a detailed analysis of the structure of the economy's dependence on imports. Imports in these tables can be classified: by origin, that is, classified into the sector in which it would be produced in the domestic

production system, regardless of whether that production sector actually imported it and by the principle of origin and the principle of purpose.

Table 3

Three-sector inter-sectoral table with separate domestic and import flows

Supply sectors	**Consumer sectors**			**Total**	**Final consumption x**	**Production X Import U**
	1	2	3			
A. Domestic production						
1	xd11	xd12	xd13	Sx d1i	xd1	X1
2	xd21	xd22	xd23	Sxd2i	xd2	X2
3	xd31	x3d2	xd33	Sx3di	xd3	X3
B. Import production						
1	xu11	xu12	xu13	Sxu1i	xu1	U1
2	xu21	xu22	xu23	Sxu2i	xu2	U2
3	xu31	xu32	xu33	Sxu3i	xu3	U3
Additional investments	D1	D2	D3	D		
Production	X1	X2	X3	X		

Note. Authors' calculation based on https://www.stat.gov.rs/en-us/oblasti/nacionalni-racuni

On the other hand, all imported products are classified by sector of origin and allocated to the production of domestic sectors. In this way, the available amount of products of individual sectors is obtained, which is distributed in the corresponding rows of the table to the reproduction consumption of individual sectors and the components of final consumption (Milojević, 2022). In that case, we do not have a separate dedicated distribution of domestic production and import of products from individual sectors. In the value structure of the production of individual sectors, only the total consumption of intermediate products by sector of origin is shown, regardless of whether they are produced in the domestic production system or imported. The same applies to the structure of each component of final consumption.

The Republic of Serbia has rich statistics of cross-sectoral tables. The tables are published by the Republic Institute of Statistics. The first table was published in 1957, for 1955. Since 1960, it has been published every other year. Tables are made at 7 levels of aggregation: 8, 12, 16, 27, 50, 76 and 98 sectors. The methodological basis is the calculation methodology of production aggregates. The relationships between economic activities in this table are shown through the quantities of products and production services that one activity supplies to another (McGilvary, 2002). The following activities are shown as production in the tables: industry and mining, agriculture, forestry, construction, manufacturing trades, transport, and as a continuation of the production process of trade. Other social activities, such as the activity of administrative bodies, education, science and culture, health and social protection, personal services and services of liberal professions, which do not generate income but participate in the consumption of the social product, are included only within the final consumption sector of the cross-sectoral tables.

Production sectors are defined through groups of specific products and services. The types of products and services that make up the content of these groups are more closely determined by the nomenclature of products and services. This nomenclature defines, at the same time, the material content of transactions between the table sectors. When creating the tables, the product or service was used as the classification unit. The calculation procedure itself, that is, the statistical identification of the sectors and transactions defined in this way in the table, was carried out through the company or product as a statistical unit of calculation. For the definition of the sector, the official classification of activity was used, in which adjustments were made in places where this classification could not ensure acceptable homogeneity of the sector and where it did not correspond to the basic assumptions of the cross-sectoral analysis. Our intersectoral tables are open-type.

All of the data used in tables is collected via official surveys and reports. Data from regular statistical surveys and a special survey conducted by the Republic Institute of Statistics entitled "Report on reproductive consumption, stocks, procurement and sales" are used to create the tables (Anton, 2005). Data from the "Comprehensive Annual Report" submitted by all companies to the Institute at the end of the year, were also used to refer to the company's activity during the year. To calculate the value of the private sector's production of agriculture, construction, transport, catering and crafts, the data of the assessment of the social product and the income of the economy's private sector are used. The imports and exports are calculated based on data from foreign trade statistics and the National Bank. Data from processing a statistical survey called "Annual Report on Investments in Fixed Assets" are used to calculate investments.

When constructing input-output tables, the product or service is used as the unit of classification. This means that the gross domestic product is defined as a simple sum of the value of products and services according to a specific nomenclature without excluding possible duplication that may occur as a result of multiple calculations of the value of raw materials and semi-finished products used for further processing within the same sector in which they were produced. The definition of the area of production in the input-output tables determines the activities whose products can be used as reproduction material.

Services of all other activities, whose products and services cannot be used as reproduction material, are not considered production and are included in the autonomous sectors of the input-output tables. By what is stated in these tables, in the area of interphase consumption, the following are not included: insurance expenses, interest, payment transaction costs, various personal expenses, such as per diems for business trips, acquirer's commissions and incidentally, which are usually included in the participant's business expenses on the market.

All purchases charged to business expenses (materials and services) were considered current, and all purchases charged to the investment account were considered capital (Backović, 2016). Therefore, the distinction between current and capital transactions in input-output tables is based on existing bookkeeping conventions. Only in exceptional cases are deviations from the current and capital transactions defined in this way.

5. ANALYSIS OF INTERSECTORAL RELATIONS

In order to introduce general symbols, which we will use in the analysis of intersectoral relations, based on which we will construct an appropriate intersectoral analysis model and quantify intersectoral dependencies, we will present an intersectoral table in the following general form.

In order to perform a complex analysis, the absolute values in the above table are insufficient. That is why it is necessary to introduce stable quantities into the analysis, namely the coefficients (Njerve, 2006). The reproduction consumption matrix in the central part of the intersectoral table, which shows the actual production links between the production sectors, will be used to calculate the matrix of technical coefficients, and they will be used for the creation of intersectoral models (Pantić, 2021). The matrix of technical coefficients represents the basic skeleton of cross-sectoral models (Žižović, 2018).

Table 4

Intersectoral analysis model

Supply sectors	Consumer sectors					Final consumption				Funds distributed
	1	2	...	N	Total	Current consumption	Investment	Export	Total	
1	x_{11}	x_{12}	...	x_{1n}	$\sum_{j=1}^{n} x_{1j}$	C_1	J_1	E_1	x_1	X_1
2	x_{21}	x_{22}	...	x_{2n}	$\sum_{j=1}^{n} x_{2j}$	C_2	J_2	E_2	x_2	X_2
...										
N	x_{n1}	x_{n2}	...	x_{nn}	$\sum_{j=1}^{n} x_{nj}$	C_n	J_n	E_n	x_n	X_n
TOTAL	$\sum_{i}^{n} x_{i1}$	$\sum_{i}^{n} x_{i2}$	...	$\sum_{i}^{n} x_{in}$	$\sum_{i=1}^{n} x \sum_{j=1}^{n} x_{ij}$	C	J	E	x	X
Depreciation	A1	A2	...	An	A					
Salaries	L1	L2	...	Ln	L					
Accumulation (Profit)	Ak1	Ak2	...	Akn	Ak					
Additional investments	D1	D2	...	Dn	D					
Domestic production	P1	P2	...	Pn	P					
Import	U1	U2	...	Un	U					
Available funds	X1	X2	...	Xn	X					

Note. Authors' calculation based on Stevanović, A., Mitrović, S. & Rajković, A. (2022). Application of information technologies and the internet in modern business. *Oditor*, *8*(2), 54-74.

6. CONCLUSION

In addition to the way some other expenses of economic organizations are treated, the presented reproduction consumption differs from the corresponding presentations of business expenses that use existing data from accounting records. The existing bookkeeping practice defined the material for reproduction in these tables from another aspect. Namely, it makes it possible to determine which transactions between market participants will be considered "capital" and which will be "current".

In the cross-sectoral tables, each sector has one row, which shows the dedicated distribution of its production to reproduction (production, cross-sectoral)

consumption of individual sectors of the production system and individual components of final consumption. The basic components of final consumption are current consumption, investment consumption and exports.

At the same time, each production system also has one column in the table, which shows the value structure of its production broken down into consumption of reproduction (cross-sectoral) products by sector of their origin and individual components of the social product. The components of social product are depreciation, personal income and accumulation. In this way, the cross-sectoral table shows how the production of individual sectors is interconnected and intertwined, forming the total gross domestic product, its dedicated distribution and value structure.

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