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Assessment of the Leontiev productive matrix of the economic development model for Tyumen region (Russia)

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ABSTRACT
Relevance. Monitoring has always been an important part of the management of regional development. Recently, this task has been gaining currency due to the development of modern information technologies of data collection and processing, citizen-government interaction and digital modelling. The task of goal evaluation, that is, comparison of the actual results with the intended ones in different spheres, among other things, requires us to build and adjust the macro-economic model of regional development and in particular to update the input-output matrix based on the region's statistical data.
Research objective. The study aims to build a table of input-output balance for the south of Tyumen region (Russia) based on the statistical data of standardized economic indicators.
Method and data. Two options for estimating the input-output matrix for Tyumen region are described. In the first option, a well-known method of adjustment of the reference input-output matrix for the priority economic sectors of Tyumen region is supplemented by the regularization of the resulting parameters according to the least squares method for the selected period. The second option is based on the aggregation of industries by subsystems based on the cost structure table of the same industries, but for the entire country, followed by the identification of the already aggregated matrix, without adjusting the result to the standard.
Results. In the first option, we obtained a table of input-output balance for 2018. The table quite accurately reproduces the invoice structure of costs and consumption. The aggregated input-output matrix, taking regularization into account, reproduces the actual costs of the region for 2016–2018 with good approximation. In the second option, the distribution of the resulting direct costs coefficients over the years does not exceed 10%.
Conclusions. The resulting estimates of the Leontiev input-output matrices meet the requirements of productivity and balance and can be used in benchmark problems for the analysis and forecasting of the economic development of Tyumen region. A variation of the functional scheme for assessing and analyzing the discrepancies between the declared and actual trajectories of the indicators based on the Leontiev matrix is proposed.

KEYWORDS
input-output model, direct cost matrix, regional development trajectory, national accounts statistics, input-output tables

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Оценка продуктивной матрицы Леонтьева модели экономического развития Тюменской области

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АННОТАЦИЯ
Актуальность. Мониторинг всегда был важной частью управления региональным развитием. В последнее время эта задача приобретает все большую актуальность в связи с развитием современных информационных технологий сбора и обработки данных, взаимодействия граждан и государства и цифрового моделирования. Решение задачи контроля соответствия заявленных целей развития и реальных достижений в различных

КЛЮЧЕВЫЕ СЛОВА
модель межотраслевого баланса, матрица прямых затрат, траектория развития региона, статистика национальных счетов, таблицы «затраты-выпуск»

сферах деятельности требует, помимо прочего, построения и настройки макроэкономической модели регионального развития и, в частности, актуализацию матрицы прямых затрат по имеющимся статистическим данным региона.

Цель исследования. Целью настоящей статьи является построение и настройка таблицы межотраслевого баланса для юга Тюменской области по статистическим данным типовых экономических показателей.

Методы и данные. Приводятся два варианта оценивания матрицы прямых затрат для Тюменской области по доступным статистическим данным экономических показателей региона. В первом варианте идентификации, известный способ коррекции эталонной матрицы «затраты-выпуск» для выбранных, приоритетных для Тюменской области отраслей экономики дополняется регуляризацией получаемых параметров по схеме метода наименьших квадратов за выделенный период. Второй вариант основан на агрегации отраслей по подсистемам на основе таблицы структуры затрат тех же отраслей, но по России, а затем идентификации уже агрегированной матрицы, без подгонки результата к эталону.

Результаты. В первом варианте получена таблица межотраслевого баланса за 2018 г, которая достаточно точно воспроизводит фактурную структуру затрат и потребления. Агрегированная матрица прямых затрат, с учетом регуляризации, с хорошим приближением воспроизводит реальные затраты региона за 2016–2018 гг. Во втором варианте разброс полученных коэффициентов прямых затрат по годам не превышает 10 %.

Выводы. Полученные оценки матриц прямых затрат Леонтьева отвечают требованиям продуктивности и сбалансированности и могут быть использованы для в модельных задачах анализа и прогноза экономического развития Тюменской области. Предложен вариант функциональной схемы оценки и анализа рассогласований заявленных и фактических траекторий показателей для региона на основе матрицы Леонтьева.

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秋明地区经济发展的投入产出矩阵

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摘要

现实性：监测一直是区域发展管理的重要组成部分。最近，由于现代信息技术在数据收集和处理、公民—国家互动和数字建模方面的发展，这项任务变得越来越重要。　监测应符合既定发展目标，并确定各个活动领域的实际成就。这需要构建和调整区域发展的宏观经济模型，特别是根据该地区现有的统计数据来确定直接成本矩阵。

研究目标：本文的目的是根据典型经济指标的统计数据，建立秋明南部地区投入产出平衡表。

研究方法：基于秋明地区经济的可用统计数据，我们给出两种直接成本矩阵。在第一个矩阵中，采用了经典的投入产出校正模型。除了秋明地区的优先经济行业分析外，还根据选定区间内的最小二乘法对参数进行调整研究。第二个矩阵是基于行业成本结构表，以俄罗斯为例，对已经汇总的模型进行识别，而不将结果与基准进行拟合。

研究结果：由第一个矩阵我们得出2018年的投入产出表，这相当准确地描述了实际的成本与消费结构。直接成本的综合模型着眼于数据的调整，非常接近于2016-2018年该地区真实的成本表。在第二个矩阵中获得的历年直接成本系数不超过 10%。

结论：投入产出表产生的直接成本矩阵具有平衡性、效率性。矩阵可用于秋明地区经济发展的分析预测任务。　文章在经典投入产出矩阵基础上，评估和分析了该地区申报指标和实际轨迹不匹配所产生的的函数变体。

关键词
投入产出模型，直接成本矩阵，区域发展轨迹，国民经济核算，投入-产出表

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Introduction

Monitoring of regional development actually comprises two different tasks: monitoring of the deviation of a region's development trajectory from the desired one and minimizing this deviation. There are quite a few documents regulating regional reporting, ranging from strategies to decrees issued to governors and regional presidential representatives (Reshetnikov, 2008). At the same time, the government has determined the structure of the reporting indicators. After the UN Conference on Sustainable Development, models of sustainable regional development of regions were devised, including various subsystems, including the economic, social, infrastructural, institutional, environmental, household subsystem, and sometimes the "human" subsystem (human resources) (Bossel, 2001; Tsibulsky et al., 2004). The regional and federal development strategies are used to select the key subsystems and indicators and their lists always include the indicators prioritized by the regional political leadership.

It is these key indicators that form the trajectory of the region's development. It is quite easy to estimate such trajectories by using official statistical data, but only for previous periods. To assess the degree of fulfillment of the regional leaders' obligations regarding the development of their regions by the end of the election period, it is essential to predict the development trajectory in order to be able to adjust the possible deviation of the actual indicators from the desired ones in advance.

In this case, there is a need for a model that could be used for predicting trends in regional development, based on the available statistical data.

One of the solutions to the problem of monitoring regional development is the Leontiev's input-output balance (IBM) model (1997) in the schemes for analyzing and forecasting the balance of a territory's macroeconomics and its growth trajectories (Miller and Blair, 2009). This trend is attracting more and more interest due to the development of modern data sourcing, data analysis technologies and information technologies for interaction between government and society.

The objective of this study is to build an IBM table for Tyumen region using a selected set of economic indicators and the available statistical data. In order to reach this objective, an assessment of the Leontiev input-output matrix must be made, and the balance ratios of output indicators, intermediate and final consumption, costs and gross value added (GVA) must be calculated.

On the one hand, the setup accuracy is determined by the completeness of the statistical data – the larger is the sampling range by year, the more stable is the identification result. On the other hand, the settings of the direct cost matrix, averaged over long intervals, may not meet the requirements for constant coefficients, partially because of the specifics of the set of indicators. One of the ways to solve this problem is to aggregate the basic set of economic indicators and thus to reduce the dimension of the input-output matrix and assess it over a relatively short statistical sampling period. This study considers various options of the aggregation of the industry performance indicators for Tyumen region's subsystems, including the household subsystem.

It should be noted that the results of our assessment of the input-output matrix for the south of Tyumen Region in the given period (2016–2019) are published for the first time.

Theoretical framework

According to Auloge (1979), Wassily Leontiev's work made it possible to simplify the Walrasian equilibrium models, which explains the Leontiev model's popularity in macroeconomic analysis. Sonis and Hewings (2001) point to the increasing interest in such models in Japan, given their modification through the connection of capital and labor. Percoco (2013) and Jensen et al. (1991) discuss the experience of applying this class of models in the strategic analysis of Europe. The historical aspect of using input-output models for the analysis of macroeconomic development in Russia is shown by Masakova (2019). Baizakov et al. (2016) consider the development of such studies in Kazakhstan. Researchers at the Far Eastern State University have proposed a vector model of regional development based on the input-output balance (IBM) with an extension for investment in each industry (Mashunin & Mashunin, 2016; Borisov & Dondokov, 2019). The Institute of National and Economic Forecasting of the Russian Academy of Sciences developed a regional input-output model, consistent with the federal one, based on statistical data similar to the system of national accounts (SNA) (Serebryakov et al., 2002). Tsybatov (2015) proposed a model and method for strategizing regional development by using the case of Samara region. Beklaryan and Pshenichnikov (2001) considered the development of a region on the basis of its infrastructure. Many researchers are considering various options for extending the IBM model to be able to take into account the impact of investment on the development of regions (Romanov, 2016, Wagner, 1993); regional clusters (Kuladzhi, 2016); and the Russian Federation as a whole (Martynov & Malkov, 2011). There are studies that create socially oriented models (Dondokov et al., 2019); use Miyazawa models (Dyrheev, 2017); and apply matrices of financial flows (Tatarkin et al., 2017).

Sayapova (2008, 2011) demonstrates that regional IBMs are used worldwide for forecasting purposes, to identify priority sectors and, eventually, develop strategies and programs. For example, in China, regional input-output tables are used to harmonize the annual and five-year plans considering different activities and global events.

Sayapova explains that the main challenge in the development of regional IBMs lies in the need to devise a methodology for a single time survey of enterprises producing goods and services. Bashkortostan was used as an example to show how the inputs (industry columns) and the outputs were determined. When comparing the resulting matrix for Bashkortostan with the reference matrix for the whole country, some coefficients differed by 2 times (for the oil and gas, machine-building industries). Sayapova makes a conclusion about the relevance of single time surveys and a carefully planned methodology for their implementation.

The input-output method was applied for the analysis of Siberian regions (Krasnoyarsk, Omsk, Novosibirsk, etc) by the Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (Mikheeva, 2006; Mikheeva, 2011).

To design the IBM model, it was proposed to adhere to the methodology of "symmetrical matrices" with a mandatory single-time survey of the technological features of production and services in the given region. It is noted that, in addition to forecasting, symmetric matrices can be used to assess the structure, diversity and volatility of the regional economy. The concept of the algorithm for designing the IBM tables lies in determining the costs based on the results of analysis and in construction of a diagonal symmetrical matrix based on obtained results. In addition, it is assumed that the technological coefficients used in forecasting are assumed to remain unchanged in comparison with the basic ones.

Shirov (2015, 2018) notes that although the input-output methodology is one of the pinnacles of economic thought, there is a perceived scarcity of such studies in Russia. In addition, he believes that the "input-output tables" are currently the only tried and tested tool for building macrostructural models of economic development.

Method and data

The basic equation of the input-output balance of production and consumption and the accepted symbols are as follows:

$$x_i = \sum_{j=1}^{n} b_{ij} + y_i, \quad (1)$$

where x_i is the gross output of the ith industry ($i = 1, 2, \ldots, n$), b_{ij} is the volume of goods and services consumed by the jth industry in the production of the ith product, y_i is the final demand for the products of the ith industry.

If divided

$$a_{ij} = \frac{b_{ij}}{x_i} \ (i, y = 1, 2, \ldots, n), \quad (2)$$

then the equation for the production and consumption IBM takes the following form

$$x_i = \sum_{j=1}^{n} [a_{ij} x_j] + y_i, \quad (3)$$

where a_{ij} are the coefficients of the desired input-output matrix A.

The balance of cost is determined by the equation

$$x_j = \sum_{i=1}^{n} [a_{ij}] x_j + z_j, \quad (4)$$

where z_j is the gross value added of the jth industry ($j = 1, 2, \ldots, n$).

The procedure for the construction and identification of matrix A recommended by the State Statistics Service of Russia is to determine the costs of production for selected industries and then determine the proportions of distribution of products for them and build a "reference" matrix for the regions of Russia.

Accordingly, two alternative settings of the input-output matrix are considered for the given region:

1) to customize the input-output matrix by using the reference matrix to the regional-level statistical data – for the south of Tyumen region;

2) to build an aggregated matrix using the average cost structure for Russia and the same industries for Tyumen region, including households as a subsystem.

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Let us now give a brief description of the economy of Tyumen region (especially its southern part) in relation to the above-described task. Some of the region's industries are characterized by the predominance of intra-regional consumption, some by inter-regional consumption. An example of the latter is the Tobolsk Chemical Plant, which consumes condensate supplied by a neighbouring region (Khanty-Mansiysk Autonomous District) and rotates its manpower. The oil industry in the region is registered at the federal level but consumes manpower at the regional level. The region's main manufacturing industries include oil production, agriculture, refineries; the services, electric power distribution, water supply, health care, culture, transport, education and research. The construction industry has made a significant contribution to the development of the region in the last decade. Based on the above, the analysis used the SNA list, consisting of 14–15 industries and "households" as the consuming industry.

There are two options for setting up the productive matrix A, which differ in the set of indicators, the way they are aggregated into subsystems, and the method of setting them up according to the available data. The breakdown by aggregated industries is necessary, since the assessment of the matrix for the full set of indicators given in the statistical data cannot be reliably performed over a relatively short observation period (2016–2019).

In the first option of constructing matrix *A*, the subsystem of product production (PP) includes agriculture, mining and manufacturing; the infrastructure subsystem (Inf.) includes production and distribution of electricity, gas, water and waste, construction, trade and other services; the social subsystem (Soc.) includes education, health care, culture and sports, the costs of administrative management and the armed forces.

In the second option, the aggregation of industries is based on the following considerations: the product production subsystem (PP) includes agriculture, oil production and refining industries; the infrastructure (Inf.) includes construction as the most significant industry, both in terms of creation and consumption; the social subsystem (Soc.) includes all services, which, in most cases, complies with the economic classifiers; the subsystem of households (Household) is described by the key indicator of the average salary by industry and by subsystem. Leontiev supposed that it was possible to include 'households' in the left side of the input-output matrix, i.e. matrix *A*. This idea was further developed in more recent studies (Leontiev, 1997; Sonis, 2001; Miller, 2009).

The structure of the productive matrix A with selected subsystems will take the following shape, where the structure of the matrix for the first option is highlighted in gray.

Table 1

Structure of the productive matrix of the region by subsystems

Subsystem	Product production	Infra-structure	Social	House-hold
Product production	a_{11}	a_{12}	a_{13}	a_{14}
Infrastructure	a_{21}	a_{22}	a_{23}	a_{24}
Social	a_{31}	a_{32}	a_{33}	a_{34}
Household	a_{41}	a_{42}	a_{43}	a_{44}

Source: developed by the authors

It should be noted that while infrastructure is not included in the costs in the case of IBM, then, here, the infrastructure matters as a subsystem of the region, including several industries (in our case, construction). The methodology for constructing matrix *A* in the first case follows the recommendations of the State Statistics Service and differs for different authors only in the method of fitting or adjusting the indicators (coefficients) of the resulting matrix to the reference matrix (Anloge, 1979). In the second case the total costs for subsystems in the shares of the total volume are determined, and the coefficients of the intermediate consumption matrix are evaluated without fitting them to the reference matrix.

Given the above, the following considerations should be made regarding the proposed approaches to assessing the input-output matrix of Tyumen region:

1) The task of building the input-output matrix can be addressed more efficiently through the aggregation of the key indicators into subsystems, which will help simplify the problem and meet the requirement of the matrix coefficients' constancy in the given period of the available actual data.

2) In the first option, the well-known approach to fitting a given input-output matrix for Russia to the data sourced in the region in the selected year is supplemented by linking the adjustment results to averaged estimates restored according to the least squares scheme (Govorkov et al., 2021) for the given period (2016–2018).

3) The second option is based on the aggregation of industries into subsystems based on the

cost structure table for Russia followed by the identification of the aggregated matrix, without any intermediate adjustment of the result to the standard.

4) Compliance with the balance ratios of the input-output balance model ensures the accuracy of the identification results.

Results

In the first variant of matrix A, the matrix corresponding to the input-output table for Russia for 2006 was chosen as the reference one[1]. The original system of headings (15 indicators in the classification OKVED 2 (Russian National Classifier of Types of Economic Activity)) is reduced to 14 indicators corresponding to the SNA data for the south of Tyumen region (see Table 2 below). The indicators were numbered and grouped into four subsystems, where PP is a subsystem, and PL is an index of economic activity. Table 2 also presents the statistics of GRP according to the SNA for Tyumen region for 2018[2]. The reference matrix of input-output coefficients, compiled according to the input-output coefficients table for Russia for 2006, is presented in Table 3.

The input-output matrix was adjusted by using the SNA data for Tyumen region for 2018 and data on the structure of disposition of the final product from the input-output table for Russia for 2006. Volumes of consumption b_{ij} were calculated on the basis of the reference input-output matrix and output values x_i according to the SNA. Input-output coefficients a_{ij} were corrected on the basis of the reconciliation of the estimated gross value added (GVA) with the SNA data. The generated volumes of final demand y_i were adjusted by using the reference structure of demand distribution presented in the input-output table (see Table 4).

The correctness of the adjustment was checked by looking at the degree of the deviation of the calculated GVA and actual statistical data – the average deviation for all the 14 indicators does not exceed 0.1%. At the same time, the distribu-

[1] Table of supply and use of goods and services for 2006 https://gks.ru/free_doc/new_site/vvp/tab-zatr-vip.htm (date of access: 01/13/22)

[2] Indicators of the system of national accounts in Tyumen region (2015–2019). Statistical Digest. Department of the Federal State Statistics Service for Tyumen Region, the Khanty-Mansiysk Autonomous District and the Yamalo-Nenets Autonomous District. 2021. Tyumen. p. 93 (date of access: 01/13/22)

Table 2

Economic indicators, their grouping by subsystems and statistical data for the south of Tyumen region for 2018

PP No.	PP	PL No.	Indicator	Output, billion rubles	Intermediate consumption, billion rubles	Gross value added, billion rubles
1	Product production	1	Agriculture, forestry, hunting, fishing and fish farming	78.8	40.8	38
		2	Mining	281.6	26.3	255.3
		3	Manufacturing	830.5	601.6	228.9
2	Infrastructure	7	Generation and distribution of electric power, gas and water, management of waste collection and disposal, environment pollution elimination	72.5	37.2	35.3
		8	Construction	272.1	176.5	95.6
		9	Wholesale and retail trade; repair of motor vehicles, motorcycles, household and personal appliances	211.1	68.7	142.4
		10	Hotels and restaurants	28.4	13.8	14.6
		11	Transport and communications	242.9	105.4	137.5
		12	Financial activities and insurance	6.7	2.6	4.1
		13	Operations with real estate, rent and provision of services, administrative, professional, research and technical activities	262.2	59.4	202.9
3	Social	4	Education	49.1	15	34.1
		5	Health care and social service delivery	50.3	16.9	33.4
		6	Activities in the field of culture, sports, recreation and entertainment management, and providing other types of services	11.6	7.8	3.8
		14	State administration and ensuring military security; social insurance	58.5	24.9	33.6
Total				2456.3	1196.9	1259.5

Source: Table of supply and disposition of goods and services in Russia, 2006; indicators of the system of national accounts in Tyumen region, 2021)

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tion of the final product reproduces the reference structure of demand presented in the input-output table fairly accurately. This factor can only serve as an indirect indicator of the accuracy of our calculations of the final demand volumes y_i, while cost balances are performed with a high degree of accuracy. Further customization requires the data on final consumption of manufactured products by households, exports, and capital formation, change in inventories, etc. for all industries, which are not provided in the available statistical sources.

Table 3

Matrix of input-output coefficients for Russia (2006)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.1884	0.0006	0.0523	0.0000	0.0012	0.0013	0.0670	0.0001	0	0.0007	0.0202	0.0202	0.0195	0.0082
2	0.0047	0.0627	0.1511	0.1629	0.0135	0.0103	0.0008	0.0241	0.0002	0.0035	0.0046	0.0050	0.0061	0.0030
3	0.2122	0.1010	0.3705	0.1304	0.4234	0.0714	0.2646	0.1868	0.0122	0.1171	0.2183	0.1163	0.2346	0.1470
4	0.0259	0.0301	0.0352	0.2480	0.0152	0.0088	0.0177	0.0339	0.0099	0.0253	0.0236	0.0684	0.0504	0.0420
5	0.0029	0.0133	0.0061	0.0206	0.0135	0.0016	0.0068	0.0204	0.0012	0.0142	0.0377	0.0169	0.0131	0.0085
6	0.0027	0.0011	0.0011	0.0013	0.0030	0.0253	0.0019	0.0088	0.0010	0.0044	0.0013	0.0009	0.0020	0.0059
7	0.0001	0.0004	0.0004	0.0005	0.0012	0.0005	0.0004	0.0019	0.0005	0.0014	0.0095	0.0075	0.0145	0.0013
8	0.0260	0.0412	0.0311	0.0221	0.0338	0.1343	0.0082	0.0923	0.0026	0.0161	0.0653	0.0096	0.0183	0.0335
9	0.0049	0.0083	0.0082	0.0144	0.0072	0.0111	0.0056	0.0122	0.1336	0.0071	0.0001	0.001	0.001	0.0061
10	0.0085	0.0441	0.0302	0.0428	0.0473	0.0923	0.0601	0.0964	0.0615	0.1108	0.1092	0.04	0.0143	0.0888
11	0.0002	0.0002	0.0010	0.0038	0.0009	0.0055	0.0003	0.0013	0.0003	0.0019	0.0005	0.0007	0.0013	0.0035
12	0.0001	0.0003	0.0002	0.0006	0.0003	0.0001	0.0001	0.0007	0.0017	0.0006	0.0004	0.0035	0.0007	0.0009
13	0.0017	0.0002	0.0001	0.0002	0.0001	0.0001	0.0003	0.0007	0.0014	0.0001	0.0013	0.0029	0.0043	0.0037
14	0.0002	0.0002	0.0005	0.0012	0.0018	0.0004	0.0034	0.0007	0.0002	0.0193	0.0330	0.0063	0.0086	0.0392

Source: Table of supply and disposition of goods and services in Russia, 2006, edited by the authors)

Table 4

Interindustry balance table adjusted according to the system of national accounts for the south of Tyumen region (2018)

		Industries as consumers															Industrial consumption	Final demand	Output
		1	**2**	**3**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**4**	**5**	**6**	**14**				
Industries as producers	1	16.614	0.054	18.206	5.68	0.045	0.001	0.031	4.053	0.177	2.975	0.001	0.035	0.029	0.524		48.56	30.24	78.8
	2	0.404	8.483	197.120	0.066	8.907	0.073	0.150	0.917	0.043	0.934	3.791	0.409	0.222	0.189		221.63	59.97	281.6
	3	18.170	8.823	338.932	22.439	66.839	3.675	6.547	61.157	1.018	35.711	3.034	12.826	1.537	9.343		589.76	240.74	830.5
	7	0.009	0.032	0.368	4.778	0.718	0.155	0.059	1.903	0.066	2.203	0.011	0.037	0.01	0.08		10	62.5	72.5
	8	2.223	3.598	27.047	0.694	64.347	0.788	1.941	13.064	0.084	2.792	0.514	1.024	2.889	2.132		123.34	148.76	272.1
	9	0.42	0.721	7.153	0.479	4.510	55.779	0.307	0.012	0.009	0.160	0.335	0.219	0.239	0.386		70.84	140.26	211.1
	10	0.13	0.693	4.731	0.918	6,400	3,350	0.858	3.934	0.063	0.392	0.179	0.258	0.358	1.016		23.28	5.12	28.4
	11	0.021	0.018	0.905	0.021	0.476	0.085	0.082	0.164	0.006	0.2	0.087	0.028	0.118	0.224		3.17	239.73	242.9
	12	0.007	0.028	0.195	0.010	0.253	0.52	0.025	0.079	0.155	0.105	0.014	0.009	0.003	0.056		1.60	5.10	6.7
	13	0.149	0.017	0.113	0.022	0.245	0.436	0.005	0.250	0.026	2.578	0.005	0.004	0.002	0.235		4.07	258.13	262.2
	4	2.217	2.632	0.306	1,500	12.494	2.993	1.305	4.727	0.599	7.665	6.347	0.46	0.189	2.667		46.24	2.86	49.1
	5	0.249	1.163	5.339	0.575	7.536	0.349	0.611	7.538	0.148	1.996	0.479	1.231	0.034	0.538		27.99	22.31	50.3
	6	0.231	0.092	0.989	0.159	3.263	0.314	0.19	0.255	0.008	0.301	0.030	0.090	2.176	0.373		8.45	3.15	11.6
	14	0.016	0.022	0.463	0.291	0.257	0.065	1.660	6.609	0.055	1.301	0.028	0.054	0.008	7.476		17.96	40.54	58.5
																Total	1196.9	1259.4	2456.3
Production costs		41	26.3	601.58	37.2	176.49	68.69	13.77	105.39	2.6	59.30	15	16.89	7.79	24.89	1196.9	=		
Added value		37.8	255.3	228.92	35.3	95.61	142.41	14.63	137.51	4.1	202.90	34.1	33.41	3.81	33.61	1259.4		=	
Output		78.8	281.6	830.50	72.5	272.10	211.10	28.40	242.90	6.7	262.20	49.1	50.30	11.60	58.50	2456.3			=

Source: Table of supply and disposition of goods and services in Russia, 2006; indicators of the system of national accounts in Tyumen region, 2021; developed by the authors

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Further correction and adjustment of the matrix is performed by using the least squares identification scheme (Govorkov et al., 2021). To this end, the original matrix was aggregated over three subsystems (see Table 1). The resulting matrix image was used as a regularizer in the least squares identification scheme according to the SNA data for 2016–2018. The matrix of aggregated costs by subsystems obtained as a result of identification (see Table 5), having the properties of productivity (the maximum eigenvalue is 0.553; the maximum sum along the columns is 0.576), reproduces the actual costs for the specified period with a good approximation (see Fig. 1 – the average deviations of costs for subsystems do not exceed 5%).

We are now going to consider the second variant of matrix *A*. By using the table "Structure of costs for production and sale of products (goods, works, services) by type of economic activity (2017–2019)"[3], we determine the share of costs by subsystems, averaging over the industries included in them. Knowing the coefficients of matrix a_{ij}, we determine b_{ij}.

[3] Indicators of the system of national accounts in Tyumen region (2015–2019). Statistical Digest. Department of the Federal State Statistics Service for Tyumen Region, the Khanty-Mansiysk Autonomous District and the Yamalo-Nenets Autonomous District. 2021. Tyumen. p. 93

Table 5

The aggregated matrix of input-output coefficients for the first option

Subsystem		1	2	3
PP	1	0.5237	0.1949	0.1868
Inf.	2	0.0415	0.1609	0.0615
Social	3	0.016	0.0572	0.1325

Source: the authors' calculations

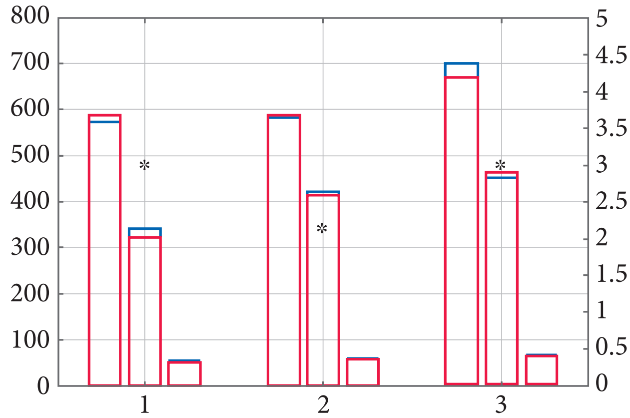

Figure 1. *Diagrams of measured (blue bars) and reconstructed (red bars) aggregated costs (marks on the left y-axis) and the average deviation between them (asterisks, marks on the right y-axis) for 3 subsystems (x-axis) for 2016–2018*
Source: indicators of the system of national accounts in Tyumen region, 2021; authors' calculations

Table 6

Breakdown by subsystems and intermediate consumption (bln rubles) of the main industries in the south of Tyumen region

Subsystems	Industries included in the subsystems (intermediate consumption in billion rubles)	2017	2018	2019
Product production	Agriculture, forestry, hunting, fishing and fish farming	36.4	40.8	43.2
	Mining	26.1	26.3	27.1
	Manufacturing	527.1	601.6	567
Infrastructure	Construction	132.8	176.3	123.6
Social	Supplying electric power, gas and steam	25.8	28.5	31.1
	Water supply, water disposal, waste collection and disposal management; environment pollution containment activities	6.8	8.7	5.4
	Wholesale and retail trade, repair of motor vehicles and motorcycles	68.8	68.7	66
	Transport and storage	96.2	94.7	114.3
	Hotel and catering business	12.9	13.8	14.4
	Activities in the field of information and communication	9.6	10.7	10.7
	Financial and insurance business	3.6	2.6	3
	Real estate business	17.3	16	27
	Professional, research and technical activities	26	28.9	56.3
	Education	14	15	19.4
	Activities in the field of health and social services	14.2	16.9	17.5
	Activities in the field of culture, sports, recreation and entertainment management	1.7	7.8	8.7
	Delivery of other types of services	25.8	1.9	2.1
Household	Salaries and enrolments	310.5	278.5	324.9

Source: indicators of the system of national accounts in Tyumen region, 2021; Statistical Digest of Tyumen region (except for the Khanty-Mansi Autonomous District – Yugra and the Yamalo-Nenets Autonomous District) in 2 parts, 2020

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Table 6 shows the intermediate consumption data for selected industries for 2017–2019. To fill in the row related to households, the data of the statistical yearbook for Tyumen region (2020) were used, namely, tables of average headcount and wages by industry[4].

Summing up the output and consumption by industries in each subsystem, we obtain aggregated indicators by subsystems (see Table 7).

The calculation of the coefficients of the productive matrix was carried out according to the order recommended by the State Statistics Service: we calculated the cost shares for each subsystem (columns), then multiplied them by the coefficient equal to the ratio of consumption to output of the subsystem. Household consumption is assumed to be equal to income taken as the average wage by subsystem, in other words, it was assumed that the fourth column does not include the consumption created by the households themselves.

Table 8 shows the coefficients of matrix A and the cost structure by aggregated subsystems for 2017–2019.

By averaging over the estimated years, we obtain a productive matrix for subsystems according to the second adjustment option (see Table 9)

[4] Statistical Yearbook: Statistical Digest. Tyumen region (except the Khanty-Mansi Autonomous District – Yugra and Yamalo-Nenets Autonomous District) in 2 parts, 2020. Tyumen. (Part II pp. 45, 71).

Table 7

Aggregate outputs and consumption (billion rubles) by subsystems

Subsystems	2017		2018		2019	
	consumption	output	consumption	output	consumption	output
Product production	589.6	955.9	668.7	1184.8	673.3	1088.9
Infrastructure	132.8	215.1	176.3	271.4	123.6	210.1
Social	304.2	880.1	314.2	947.3	307.8	1015
Household	310.5	2155	278.5	2519	324.9	2430

Source: indicators of the system of national accounts in Tyumen region, 2021; authors' calculations

Table 8

Input-output coefficients of the Leontiev model for the south of Tyumen region for 2016–2019, estimated on the basis of the cost structure by industry

2017								
Input-output coefficients					**Shares of costs by subsystems (%)**			
Subsystem	**PP**	**Inf.**	**Soc.**	**Household**	**PP**	**Inf.**	**Soc.**	**Household**
Product production	0.355	0.357	0.12	0.013	58	58	35	10
Infrastructure	0.05	0.019	0.02	0.025	8	3	6	19
Social	0.145	0.123	0.11	0.034	23	20	33	26
Household	0.062	0.12	0.09	0.059	10	19	26	45
2018								
Input-output coefficients					**Shares of costs by subsystems (%)**			
Subsystem	PP	Inf.	Soc.	Household	PP	Inf.	Soc.	Household
Product production	0.31	0.37	0.116	0.012	56	57	35	10
Infrastructure	0.045	0.02	0.02	0.023	8	3	6	19
Social	0.143	0.13	0.11	0.028	26	20	34	23
Household	0.056	0.123	0.078	0.056	10	10	23	47
2019								
Input-output coefficients					**Shares of costs by subsystems (%)**			
Subsystem	**PP**	**Inf.**	**Soc.**	**Household**	**PP**	**Inf.**	**Soc.**	**Household**
Product production	0.35	0.32	0.12	0.013	56	54	40	10
Infrastructure	0.05	0.015	0.018	0.026	8	2.6	5.9	20
Social	0.15	0.124	0.09	0.03	25	21	31	22
Household	0.06	0.13	0.066	0.06	10	22	22	48

Source: indicators of the system of national accounts in Tyumen region, 2021; Statistical Digest of Tyumen region (except for the Khanty-Mansi Autonomous District – Yugra and the Yamalo-Nenets Autonomous District) in 2 parts, 2020; authors' calculations

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Table 9

Coefficients of the aggregated input-output matrix for the second option

Subsystem		1	2	3	4
Product production	1	0.338	0.349	0.119	0.013
Infrastructure	2	0.048	0.018	0.019	0.025
Social	3	0.146	0.126	0.103	0.031
Household	4	0.059	0.124	0.078	0.058

Source: the authors' own calculations

The productivity indicators in this case are as follows: the maximum eigenvalue is 0.45; the maximum sum along the columns is 0.617.

Discussion and Implications

Based on results of the research, it can be concluded that the main research problem was solved by using two options for Leontiev's input-output matrices adjustment according to the aggregated economic indicators for Tyumen region. In the second option, households were directly included in the structure of production and consumption. The resulting coefficients (a_{ij}) of the aggregated matrix in the first option reproduce the actual cost for 2016–2018 with acceptable accuracy, and in the second option they are quite stable over the analyzed period (2017–2019) even with a significant fluctuation in consumption. In addition, the conditions for the productivity of input-output matrices are met for both customization options.

Thus, the proposed options for setting up an input-output matrix by aggregated indicators can be used to update the input-output models to analyze and forecast the economic development of Tyumen region. It is possible to build a functional model for assessing and analyzing discrepancies between the declared and actual trajectories of the indicators for a given region (see Fig. 2).

The following notation is used in Figure 2:

– $x_Э(k)$ is the reference strategy for regional development;

– $A_Э$ is the economic structure of the given region (initial representation);

– $z_Э(k)$ is the expected total volume of costs in the case of the implementation of the plan according to $A_Э$ structure: $z_Э(k) = A_Э x(k)$;

– $x(k)$, $z(k)$ are the observed statistics on the outputs and costs of the actual state of development of the region;

– A is the actual production structure of the region, which determines the connection $z(k) = Ax(k)$, while the actual status of A is unknown, yet $A_Э$ is our a priori idea of A;

– $\hat{A}$ is the current assessment of the real production structure of the region, obtained by U identifier based on the results of processing the actual sata $\langle x(k), z(k), k \in \{1, 2, \ldots\}\rangle$, where k is the number of the year in the statistical sample, i.e. $\hat{A} = U(x(k), z(k), k \in \{1, 2, \ldots\})$.

It is assumed that estimate $\hat{A}$ is more in line with actual A than the original representation $A_Э$, i.e. $\| A - \hat{A} \| \le \| A - A_Э \|$. In $\hat{A}$ conditions for the achievement of $x(k) \to x_Э(k)$, the structure and volume of costs should be evaluated by using the actual data, i.e.

$$\hat{z}_Э(k) = \hat{A}x(k), \quad (5)$$

where $\hat{z}_Э(k)$ is the estimated cost that is used as a reference outcome trajectory.

The desired discrepancy between the declared and actual development trajectories of the region in terms of costs and outputs will be assessed as follows:

– $\Delta x(k) = x_Э(k) - x(k)$ is the observed non-fulfillment of the plan;

– $\Delta\hat{z}(k) = \hat{z}_Э(k) - z(k)$ is the assessment of the reasons for non-compliance and required cost adjustment.

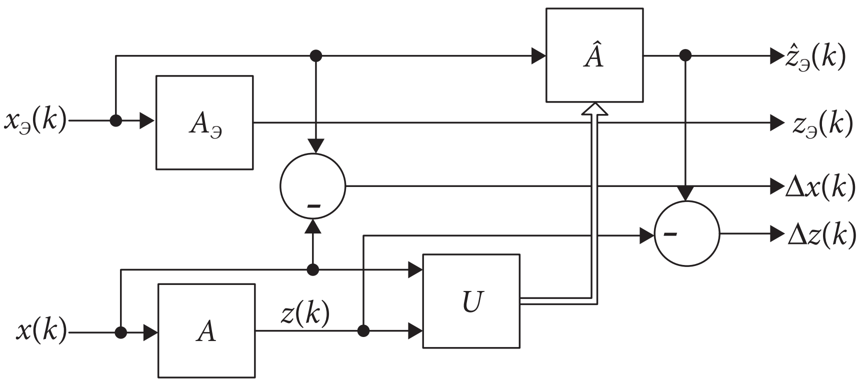

Figure 2. *Structural diagram of the functional model for assessing the indicators of regional development and their comparison with the actual data*

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The proposed solution can be tested as a software tool for the analysis of a planned development strategy, for modeling of the key economic indicators and comparison of the planned outcomes with the actual regional statistical data. This tool provides an opportunity to control not only the compliance of the actual trajectories of regional development with the declared trajectories, but also the capability of the regional government to adjust these key indicators depending on the directives issued by the federal government and the President. In the future, the model and software package can be upgraded to take into account additional economic, social and information factors. In future research, the model and software can be further improved to give due regard to other economic, social and information factors of regional development and thus be used to assess the performance of regional governors, including the level of citizen satisfaction.

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