Estimating of Stochasticity of Technological Coefficients in Russian Input-Output Tables

Alsu Sayapova[a], Leysan Mazitova[b], Rustam Ishbulatov[b*]

[a]Institute of Economic Forecasting of Russian Academy of Sciences
Address: D -418, Nahimovski Prospect, Moscow, 117418, Russian Federation.
E-mail: asajaf@mail.ru

[b]Bashkir State University, Faculty of Economics
Address: K.Marx st. 3/4, Ufa, 450074, Republic of Bashkortostan, Russian Federation.
E-mail: MazitovaLD@mail.ru, IshbulatovRS@googlemail.com

Abstract

The technological coefficients' errors in Russian input-output tables, both at the national and regional levels, arise from numerous sources. At the national level such sources are: biases in data of one-time-only survey of production cost structure, selective character of the survey, biases in the estimation of the shadow economy, errors of the transition from SUT to SIOT, etc. At the regional level, apart from the above sources, statistical data required for the drawing up of the input-output tables are incomplete, particularly it concerns incomplete data on regional import-export operations. Besides, the survey-based regional tables simply have not been constructed for a long time in Russia. The few studies, that rely on the regional IOT, use the regionalization of national tables of Russia. The latter is an additional source of possible deviation of the regional technological coefficients from their true values. The expected reforms regarding regional authorities do not predispose towards the construction of regional input-output tables based on the survey of production cost structure for 2011. Therefore, nothing remains but to evaluate possible errors in the regionalized input-output tables, treating their parameters as stochastic variables. In this respect, we consider methodical approaches to the determination of the confidential intervals for the regional technological coefficients, to the assessment of the impact of such errors on the accuracy of calculations for endogenous variables in input-output model, to the assessment of the model's stability and identification of technological coefficients, in relation to which the model is particularly sensitive. The methodical approaches are being implemented on the example of the regional input-output table developed by the authors for the Republic of Bashkortostan.

Keywords: regional input-output tables, technical coefficients, stochastic variables.

Introduction

In the overwhelming majority of applied problems the researcher deals with inaccurate initial data. The uncertainty of the latter is generated by a variety of factors. Inaccuracy of initial data is a permanent satellite of economic researches. To the same extent it refers to the Input-Output tables.

Before proceeding to analyzing accuracy of the Input-Output tables and projections based on it, let us clarify some definitions. Almost without exception economic variables can be treated as random and uncertain. Both notions of uncertainty and randomness occur in scientific literature. Quite often these notions are identified. We hold to the viewpoint that randomness is a special case of uncertainty, i.e. the variable under study is considered to be a stochastic variable with the prescribed (guess) probability density function.

1. Sources of uncertainty of the IO tables and the description models applied

Broadly speaking, randomness and uncertainty may result from measurement: through measurement and round-off errors; projections: through incomplete information and procedure errors; expert estimations: through subjectivity and round-off errors. As the below mentioned projections based on the IO model will show, the whole aforementioned set applies. Variables and parameters of the IO model undoubtedly refer to the "uncertain" category.

At present various description models for uncertain data are employed. In this paper we are going to give consideration to probabilistic and interval models.

The probabilistic-statistical model is based upon the assumption that the x variable under study is a random value with a prescribed probability density function. This model can be referred to classic models due to its deep theoretical and procedural elaboration for a variety of important applications, including regression, correlation, factor and dispersion analyses.

Within the interval model the uncertainty of the x parameter is described by the boundaries of its possible values as follows: $[x] = [x_{\min}, x_{\max}]$. As distinct from the probability theory, no probability measure is prescribed within the $[x]$ interval, i.e. all the values within the interval are considered to be equally possible (don't confuse with "equiprobable").

Based on the uncertainty types let us specify its sources which result in inaccuracies of statistic data of regional basic IO tables and in projections.

1) inaccuracy of the data concerning production cost structure of companies and businesses, used to estimate elements of quadrant I of a symmetric table, i.e. response errors;

2) sample survey of production cost structure;

3) inaccuracy of compiling the Supply Table. This table shows formation of goods and services supply through in-house production and import. Statistical recording of the latter is a special problem in regional economics;

4) the impact of shadow economy factor. Large share of hidden production, which is estimated in general, reduces reliability of the calculation;

5) the use of the RAS technique in balancing supply and use of goods and services. The use of the RAS technique is predetermined by its simplicity, popularity and applicability for distribution of minor imbalance. That is why a comparatively large alteration of interindustrial flows in quadrant I of a symmetric table after application of the technique must raise doubts in their reliability;

6) existence of industries where the cost structure takes into account secondary output only, or otherwise was identified by analogy with the production technology.

The projection IO models include inaccuracies for justification of industry costs, incompatibility of tables for different years due to variety of industry lists, lack of procedures to forecast correlations between costs of regional and imported goods, ambiguity of scientific and technical progress trends and its impact upon direct input coefficients.

2. Estimation of endogenous parameters' inaccuracies of the IO model for the Republic of Bashkortostan

The results of impact from the aforementioned factors are estimated for direct input coefficients for the Republic of Bashkortostan[1]. Inaccuracies of the direct input coefficients were calculated basing upon the comparative analysis with the analogous coefficients of national symmetric input-output table of the Russian Federation, basing upon direct input coefficients difference calculated before and after balancing the supply and use of goods and services, coefficient deviations before and after employing the RAS technique. In the case under consideration an interval approach to estimating uncertainty of direct input coefficients was employed. Doubtful cells are found, essentially, in the following industries: "other fuel industry", "other manufacturing", "other business activities", the latter two often being balancing. Appendix 1 gives intervals of possible direct input coefficients values for all economy industries with inaccuracies of these parameters taken into account, except for the "other fuel industry", "other manufacturing", "other business activities" columns.

[1] The latest cost structure survey in Russia was performed for the year 1995. The Input-Output tables for the ensuing years were calculated basing upon the 1995 survey. In this paper we investigate the 1995 regional Input-Output tables due to higher precision of such tables.

Whenever there is an uncertainty factor in the initial information, i.e. inaccuracies of direct costs coefficients, the most important task is to estimate precision of endogenous variables of the IO model.

Appendix 2 gives estimations of intervals for industry outputs on the basis of IO tables for the Republic of Bashkortostan, taking into account intervals of direct input coefficients from Appendix 1. The table presents relative deviations (in %) of right and left boundaries of possible industry output values from their actual values.

The interval boundaries for industry output vectors were received via the formulae:

$\underline{X} = (E - \underline{A})^{-1} Y$ and $\overline{X} = (E - \overline{A})^{-1} Y$,

where $\overline{A} = \left\| \overline{a}_{ij} \right\|$ and $\underline{A} = \left\| \underline{a}_{ij} \right\|$ are matrixes of maximum and minimum possible values of direct input coefficients a_{ij}, obtained as a result of estimating the inaccuracies of exogenous information of basic IO table. At the same time uncertainty in the final demand vector component Y is not taken into account.

It is obvious that the following inequations hold for each of the vector components $\underline{X}$, X and $\overline{X}$

$$\underline{X}_j \le X_j \le \overline{X}_j,$$

i.e. $(E - \underline{A})^{-1} = E + (\underline{A})^1 + (\underline{A})^2 + (\underline{A})^3 + ... \le E + (\overline{A})^1 + (\overline{A})^2 + (\overline{A})^3 + ... = (E - \overline{A})^{-1}$.

Let us note that maximum and minimum possible values of the final demand vector components ($\overline{Y}$ and $\underline{Y}$ respectively) are estimated the following way according to the available lower $\underline{A}$ and upper $\overline{A}$ boundaries of the matrixes of direct input coefficients without regard to uncertainty in the X production volumes:

$$\overline{Y} = X - \underline{A}X = (E - \underline{A})X,$$

$$\underline{Y} = X - \overline{A}X = (E - \overline{A})X.$$

In other words, in order to identify the upper limit of final demand vector component the lower limits of direct input coefficients are used, and vice versa.

Another approach to estimating the impact of inaccuracies of direct input coefficients upon the precision of endogenous IO model variables calculations consists in that technical coefficients are considered to be stochastic variables. Consequently, the volumes of total outputs are stochastic variables. Taking into account that many economic parameters comply with the normal distribution, which is a limiting one and fully characterized by the first two moments, we assume that the distribution law of total outputs is normal:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-m)^2}{2\sigma^2}}$$

where the parameters of basic Input-Output tables can be used as *m* (mathematical expectation), and σ^2 (variance) can be estimated according to the three sigma rule. For example, when the interval $[\underline{a}_{ij}; \overline{a}_{ij}]$ is available $\underline{a}_{ij}$ is minimum of possible values of the a_{ij} element, whereas $\overline{a}_{ij}$ is, accordingly, a maximum value, the value of the second central moment $D(a_{ij})$ is set in accordance with the three sigma rule, i.e.

$$\overline{a}_{ij} - \underline{a}_{ij} = 6\sqrt{\sigma^2(a_{ij})},$$

or in case of relative mathematical expectation a_{ij}^0 of the a_{ij} parameter distribution

$$\overline{a}_{ij} = a_{ij}^0 + 3\sqrt{\sigma^2(a_{ij})},\ \underline{a}_{ij} = a_{ij}^0 - 3\sqrt{\sigma^2(a_{ij})}.$$

Unsophisticated calculations will help derive **σ** from the mentioned correlation.

After estimating the inaccuracies of direct input coefficients and their impact upon the endogenous variables of the IO model it is necessary to estimate the capability of using the model for decision making under uncertainty, i.e. to specify to what extend the IO model is stable in relation to the technological coefficients; as well as fluctuations of which exogenous parameters markedly affect the output variables.

Stability is a property of the model, which is considered in relation to a certain parameter and which is characterizing model's ability to provide permitted small deviation of calculation from basic data (in this case from the basic Input-Output table) (usually ±5%). We study stability of the IO model comparing to all direct input coefficients. In this case the $\frac{\overline{X}_j - \underline{X}_j}{2X_j^0}$ (*j=1,...25*) relations have been taken in the capacity of model stability parameters, which reflect the impact of uncertainty in the initial table data (Appendix 3). They characterize relative inaccuracy of total outputs for each economy industry X_j, connected with the direct input coefficients boundaries $\underline{A}$ and $\overline{A}$.

The data in Appendix 3 show that the parameters of $\frac{\overline{X}_j - \underline{X}_j}{2X_j^0}$ of the following five industries exceed the 5%-limit: "power industry", "gas industry", "coal industry", "trade", "other types of activity in production of goods and services". Products of such industries as "power industry", "trade" are directed to almost all industries of economy and often constitute a large share of costs. That is why inaccuracies of direct input coefficients of the products of these industries markedly affect the accuracy of output data. Besides, instability of the "other business

activity" industry is explained by the fact that this industry is a balancing one, i.e. inaccuracies of direct input coefficients in the industry are quite significant. The instability of the "gas industry" and "coal industry" is affected by the low volume of total outputs.

Conclusion

In order to specify the direct input coefficients in relation to which the model is particularly sensitive, the stability of the model is checked in less rigid conditions. At the same time we have identified the direct input coefficients the doubling of which will result in output increase of more than 10% in at least one industry. The research has indicated that the amount of these direct input coefficients is insignificant (9% of the total number). All of these refer to the so called "important" coefficients. They include first of all input coefficients for oil recovery products to oil refining products; trade services, agency business and public catering input to oil refining products; agriculture and forestry product input to food industry product.

In this paper coefficients are important when the insignificant alteration of their parameters can lay heavy impact upon the output variables of the model, specifically, total output volumes. Cells of important coefficients for industrial branches can be found in Appendix 4. The research has revealed that among the total amount of direct input coefficients of the Input-Output symmetric table for the Republic of Bashkortostan with 25 industries in the list there are 160 (26% of the total number of coefficients) important coefficients, which cover 96% of the interindustrial flows in the region's economy. As a rule, these are input coefficients for the products of electric energy, oil refinery, chemical industry, machinery and equipment, i.e. industries which constitute a significant share of intermediate consumption. It has been revealed that important coefficients include first of all diagonal components of industries with large output volumes. The absolute value of these coefficients exceeds the ones of other coefficients.

Thus, it was identified that the IO model is sensitive to important direct input coefficients, the accuracy of which is of special significance. It also revealed that stability of the model can be enhanced by specifying primarily these parameters. On the other hand, estimation of technological coefficient inaccuracies shows that inaccuracies of important coefficients are not so high. The latter allows us claiming that the IO model may be used for analytical calculations, as well as short and long-term projections.

References

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Appendix 1

Uncertainty boundaries of the direct input coefficients (according to Input-Output tables for the Republic of Bashkortostan). The left boundary demonstrates possible minus **% deviation from the basis value, whereas the right boundary demonstrates possible plus **% deviation from the basis value

Branch	Power industry		Extraction of crude petroleum		Manufacture of refined petroleum products		Gas industry		Coal industry		Ferrous metallurgy		Nonferrous metallurgy	
Power industry	5%	2%		1%	5%		4%	5%	9%		7%			1%
Extraction of crude petroleum				5%	1%		1%							
Manufacture of refined petroleum products	1%				5%		4%		10%		3%			1%
Gas industry	1%	0%		2%	4%		3%				3%			
Coal industry		13%								3%		13%		17%
Other types of fuel		4%												
Ferrous metallurgy		3%	8%	4%		1%	8%					10%		6%
Nonferrous metallurgy		14%		12%		13%		7%				11%		3%
Manufacture of chemicals and chemical products	14%		13%		18%		17%		13%		18%		13%	
Manufacture of petrochemical products		1%			3%		20%				2%			3%
Machinery and equipment		4%		8%		6%	3%		4%			30%		4%
Wood and wood products industry	100%	7%				4%		5%	12%		3%			23%
Construction materials		6%		6%	7%		7%					10%		33%
Light industry												6%		5%
Food industry	14%				7%		100%		21%					
Other manufacturing		3%			7%								11%	
Construction														
Agriculture											13%		13%	
Transport and communication	2%		5%		4%		6%		8%		5%		6%	
Trade	3%				6%		4%	10%	10%		5%			2%
Other business activities		2%		23%		23%		23%	8%		2%	10%	1%	9%
Housing and communal services		3%		4%			10%		6%			2%	8%	
Health, physical culture and social welfare services, education, culture and art	0%			1%	50%		11%				1%			43%
Science and scientific servicing, geology and exploration survey, geodetic and hydrometeorological services				4%	6%		6%							
Services in financial intermediation, insurance, government administration and non-governmental organizations		1%		2%	12%		12%		8%			10%		4%

Branch	Manufacture of chemicals and chemical products		Manufacture of petrochemical products		Machinery and equipment		Wood and wood products industry		Construction materials		Light industry		Food industry	
Power industry		3%		7%		4%		1%		1%	2%		3%	
Extraction of crude petroleum		7%		7%	2%									
Manufacture of refined petroleum products	2%			7%		4%	1%		3%		11%			18%
Gas industry		7%		7%	1%		5%	5%	3%		12%			22%
Coal industry						18%				8%		11%		26%
Other types of fuel								7%						
ferrous metallurgy		9%		5%		5%		7%		2%	10%	10%		21%
Nonferrous metallurgy		11%		14%		19%				13%		15%		29%
Manufacture of chemicals and chemical products	8%		15%		3%		7%		3%		3%			16%
Manufacture of petrochemical products	5%	5%	3%			5%		1%	3%		5%			16%
Machinery and equipment		9%		2%	4%		4%		10%	10%	10%	10%		12%
Wood and wood products industry		6%		18%		1%		1%		3%				20%
Construction materials	10%	10%	4%		1%			4%	5%	5%		10%		15%
Light industry		11%		14%		5%		18%		6%		4%		27%
Food industry	4%	4%	12%		5%		5%		15%		7%			3%
Other manufacturing	5%		10%			10%	19%		17%		10%	10%		15%
Construction														
Agriculture											26%		7%	
Transport and communication	3%		5%		2%		3%		6%		6%			18%
Trade	3%		5%		3%		4%		5%	5%	12%			13%
Other business activities		12%		12%	5%	5%	10%	10%	1%	2%	10%			
Housing and communal services	3%			2%	11%			4%		10%	7%			20%
Health, physical culture and social welfare services, education, culture and art		18%		18%	4%		8%			10%	13%			17%
Science and scientific servicing, geology and exploration survey, geodetic and hydrometeorological services					90%				10%				10%	10%
Services in financial intermediation, insurance, government administration and non-governmental organizations		7%		7%	10%	10%	10%	10%	12%		11%			21%

Branch	Construction		Agriculture		Transport and communication		Trade		Housing and communal services		Health…		Science…		Government…	
Power industry		3%		16%					4%	6%		3%		5%	9%	2%
Extraction of crude petroleum		1%				4%		10%	1%							
Manufacture of refined petroleum products	4%			11%	1%		2%	4%			2%		4%		7%	
Gas industry	3%			17%			10%	3%					3%			
Coal industry		10%		34%		13%				11%		13%		9%		
Other types of fuel				14%		4%							16%			
ferrous metallurgy		3%		18%		12%	10%		1%	12%		3%	19%			
Nonferrous metallurgy		8%				18%	10%		14%	15%		18%		100%		
Manufacture of chemicals and chemical products	4%		7%		4%	8%	10%	10%		2%		1%	18%		2%	
Manufacture of petrochemical products	3%			6%			10%	10%			3%			3%	5%	
Machinery and equipment	2%			5%	4%		5%		2%			1%		5%	8%	
Wood and wood products industry				12%		3%			2%	3%		1%		2%	15%	
Construction materials				15%		3%		10%	2%	4%	2%			1%	1%	
Light industry	3%			11%				1%		4%	2%		3%		5%	
Food industry	14%				13%		8%	12%			3%		9%		10%	
Other manufacturing	10%	10%			10%		8%	11%				1%	8%		3%	
Construction																
Agriculture			6%				14%	30%			28%		23%			
Transport and communication				10%			10%	4%		10%			4%		5%	
Trade	10%	10%		14%			10%	5%		10%				3%	1%	
Other business activities				18%			5%		3%	5%				4%		6%
Housing and communal services				20%			5%	14%		5%					3%	
Health…				12%			10%	8%		10%			5%		6%	
Science…								10%						2%		
Government administration…				13%			10%	2%		10%			10%	10%	9%	

Appendix 2

Relative deviations of the right and left boundaries of possible production volume values from the actual values (per branch of economy, %)

Branch	Relative deviation	
	left boundary	right boundary
Power industry	-5,2	7,3
Extraction of crude petroleum	-3,1	3,6
Manufacture of refined petroleum products	-1,8	1,9
Gas industry	-26,4	35,3
Coal industry	-4,6	20,8
Other types of fuel	-2,6	6,5
Ferrous metallurgy	-1,6	4,8
Nonferrous metallurgy	-1,4	6,8
Manufacture of chemicals and chemical products	-6,7	1,0
Manufacture of petrochemical products	-1,6	0,9
Machinery and equipment	-4,3	3,3
Wood and wood products industry	-2,6	5,8
Construction materials	-1,4	1,6
Light industry	-1,2	3,1
Food industry	-1,5	1,0
Other manufacturing	-5,4	2,7
Construction	0,0	0,0
Agriculture	-5,6	0,6
Transport and communication	-4,4	3,3
Trade	-11,8	10,7
Other business activities	-4,7	8,9
Housing and communal services	-0,5	0,5
Health, physical culture and social welfare services, education, culture and art	0,0	0,0
Science and scientific servicing, geology and exploration survey, geodetic and hydrometeorological services	-0,6	0,6
Services in financial intermediation, insurance, government administration and non-governmental organizations	-0,4	0,4
TOTAL	**-3,4**	**2,9**

Appendix 3

Stability parameters of the IO model in relation to inaccuracies of direct input coefficients

Branch	$\frac{\overline{X}_j - \underline{X}_j}{2X_j^0}$, **в %**
Power industry	6,3
Extraction of crude petroleum	3,3
Manufacture of refined petroleum products	1,8
Gas industry	30,8
Coal industry	12,7
Other types of fuel	4,6
Ferrous metallurgy	3,2
Nonferrous metallurgy	4,1
Manufacture of chemicals and chemical products	3,9
Manufacture of petrochemical products	1,2
Machinery and equipment	3,8
Wood and wood products industry	4,2
Construction materials	1,5
Light industry	2,1
Food industry	1,3
Other manufacturing	4,1
Construction	3,1
Agriculture	3,9
Transport and communication	11,2
Trade	6,8
Other business activities	0,5
Housing and communal services	0,0
Health, physical culture and social welfare services, education, culture and art	0,6
Science and scientific servicing, geology and exploration survey, geodetic and hydrometeorological services	0,4
TOTAL	**3,1**

Appendix 4

Cells of important direct input coefficients per industry in the Republic of Bashkortostan (highlighted in grey)

Branch	Power industry	Extraction of crude petroleum	Manufacture of refined petroleum products	Gas industry	Coal industry	Ferrous metallurgy	Nonferrous metallurgy	Power industry	Manufacture of chemicals and chemical products	Manufacture of petrochemical products	Machinery and equipment	Wood and wood products industry	Construction materials	Light industry	Food industry	Other manufacturing
Power industry																
Extraction of crude petroleum																
Manufacture of refined petroleum products																
Gas industry																
Coal industry																
Other types of fuel																
Ferrous metallurgy																
Nonferrous metallurgy																
Manufacture of chemicals and chemical products																
Manufacture of petrochemical products																
Machinery and equipment																
Wood and wood products industry																
Construction materials																
Light industry																
Food industry																
Other manufacturing																