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SIGNIFICANCE AND NECESSITY OF UPDATING THE MATRIX OF TECHNICAL COEFFICIENTS IN INPUT-OUTPUT ANALYSIS

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Abstract: *Technical coefficients as products, or rather as derived categories derived from empirical data woven into cross-sectoral tables, are conditioned primarily by technical progress as well as substitutions among inputs in the process of reproduction in the national economy.*

The dynamics of technical progress in the production structure of the national economy is very complex and uneven. Depending on the observed period, large differences between production sectors are possible in terms of the size of their technical progress. It depends primarily on the trend in the expansion and application of new production processes, the introduction of new raw materials and finally the substitution of a certain part of the input in production processes.

We can see that recently there has been a trend of increasing specific consumption of electricity and natural gas as a result of intensifying the mechanization of production processes and insisting on cheaper and renewable energy sources.

The demand of economic policy makers, especially Western countries, to replace the use of fossil energy sources with solar and atomic energy, as well as greater use of biogas, energy from wind farms and electricity production using tidal energy is becoming more frequent. At the same time, there is a rationalization of the consumption of certain raw materials and reproductive material as a result of the use of robotics in industry, and there are also many forms of substitution of natural materials with artificial ones.

The general trend of technical progress in the national economy must be understood as the sublimation of all individual or individual efforts and investments in changing and improving technology and production functions in the relevant segments of the national economy. Therefore, technical progress depends exclusively on the dynamics and size of investments.

Since technical coefficients show direct dependence between production sectors of a national economy, their size depends on the technological equipment of the production system and they change depending on the dynamics and size of technical progress, there is a need to constantly update the matrix of technical coefficients and the inevitable use of intersectoral models as tools for predicting their changes.

Having in mind that the priority is the use of technical coefficients in predicting the future structure of mutual relations of production sectors in the national economy, the measure by which the matrix of technical coefficients realistically reflects the macro production structure of the economy will also be a measure of objectivity in their economic analysi as well as in the prediction of further cause-consequence relationship among the sectors of production.

Keywords: *fabrication effects, substitution effects, input-output analysis, interphase consumption, intersectoral tables, RAS method, production sectors, structural proportion, technical coefficient, technical progress, cause-and-effect relationships, vector.*

1. CROSS-SECTORAL TABLES AND TECHNICAL COEFFICIENTS

The cross-sectoral tables show the actual production links between the sectors of production and represent the basis for calculating the matrix of technical coefficients.

The links between the production sectors of a national economy are woven into the reproductive consumption matrix located in the central part of the cross-cutting table.

In that part of the cross-sector table, there are elements xij which represent a part of the sector's production and which is spent in the reproductive consumption of sector j. The question now is why sector j spent xij products of sector i.

Sector j spent that value of the sector's production in its reproductive consumption to produce the value of its production Xj. From this follows a logical conclusion: if the sector j consumed xij of the products of the sector and in order to realize Xj of its production, it means that for each unit of its production it spent on average xij of the products of the i-th sector.

In order to perform a complex analysis, the absolute values in the above table are insufficient, so stable parameters are introduced into the analysis, and these are the coefficients.

The matrix of technical coefficients is the basis of all intersectoral models.

Technical coefficients are obtained from intersectoral tables as follows:

$$aij = \frac{\boldsymbol{xij}}{\boldsymbol{Xj}}$$

It shows the average consumption of i-th sector products per unit of production of the j-th sector. Therefore, the notion of technical coefficient corresponds to some extent to the notion of consumption norms from the jargon of technicians. The technical coefficient also shows how much the value of production of the i-th sector is directly dependent on each unit of production of the j-th sector.

Thus, the technical coefficient shows us the direct dependence of the i-th sector and sector j.

It shows, further, which part of the production of the sector i directly depends on the size of the total production of the sector j.

Furthermore, the technical coefficient shows the maximum possible production of the sector, given the available quantity of reproductive products of the sector and which are available to meet its reproductive needs.

$$\boldsymbol{Xj} \leq \frac{\boldsymbol{xi}}{\boldsymbol{aij}} \quad \text{gde je } (i,j=1,2,\ldots\ldots,n)$$

This means that for a certain size of the production of sector j, the appropriate size of the products of sector i must be spent. Therefore, the available quantity of intermediate products of the sector directly affects the size of the production of sector j.

It is also quite logical that the value of each technical coefficient is non-negative:

$$a_{ij} > 0; (i,j = 1,2,\ldots\ldots,n)$$

Finally, it is quite clear that the value of production of each sector is greater than the value not only of any of its inputs but of all inputs combined.

When we say that the technical coefficient aij shows the size of the production of the sector and for each unit of production of the j-th sector, we assume complete proportionality of the technical coefficients. This assumption means ignoring the operation of the law of rising and falling revenues. Therefore, it is assumed that the consumption of products of sector i in the reproductive consumption of sector j is directly proportional to the size of production of sector j. The factor of this proportionality is the technical coefficient aij.

Many empirical studies have shown, due to changes in technical coefficients during economic development, that projections based on a cross-sectoral model are more uncertain if the matrix of technical coefficients of that model is older in time.

When conducting macroeconomic policy, as a rule, we have an intersectoral table and a matrix of technical coefficients that refer to an earlier year, because the original statistical intersectoral tables, due to the complexity of their production and high costs, are compiled only in intervals of two to five years or more.

2. SIGNIFICANCE AND NEEDS OF UPDATING THE MATRIX OF TECHNICAL COEFFICIENTS

Intersectoral input-output tables that represent the basis for calculating technical coefficients are made, as a rule, every two and sometimes every five years. The reasons for such a long period of development and innovation of intersectoral tables lie in the fact that it is a very complex and expensive process.

Namely, the data on the basis of which they are made are drawn from the data of each individual production sector, and even in certain situations they are taken from an individual company. We can see a similar example that is even more complicated and complex when it comes to the census. Unlike the preparation of intersectoral tables, the census is conducted every eleven years.

Having in mind the stated fact as well as the knowledge that the value of each individual technical coefficient is subject to constant change, the need for their continuous updating automatically arises. If this were not done, technical coefficients would not realistically reflect sectoral relations in the national economy over time, and thus would be an unreliable toolkit for the analysis of intersectoral relations as well as for input-output analysis.

There are several problems that arise when using a cross-sectoral model in the design and alignment of structural proportions.

The first problem is the need to update and evaluate the cross-sectoral table for the base year from which we start in all planning calculations. However, during the planning period, there are certain changes in certain technical coefficients.

In order for the matrix of technical coefficients to show the real cross-sectoral production links that will be established during the planning period, it is necessary to estimate the expected changes in technical coefficients.

The second problem is the adequate adjustment of the matrix of technical coefficients for the purposes of specific forecasting and design of economic structure.

Changes in technical coefficients are conditioned primarily by technical progress and substitutions among individual inputs in the production process.

The process of spreading technical progress in the production structure of the economy is very complex. On the one hand, it manifests itself in the form of a certain trend of gradual spread of new production methods, introduction of new inputs and in the form of substitutions in the structure of inputs in the entire production system.

Technical progress in the production structure of the national economy is very complex and uneven. It varies from sector to sector and is even different for companies that produce the same or similar products and services within one sector. It depends primarily on the trend in the expansion and application of new production processes, the introduction of new raw materials and finally the substitution of a certain part of the input in production processes.

We can see that recently there has been a trend of increasing specific consumption of electricity and natural gas as a result of intensifying the mechanization of production processes and insisting on cheaper and renewable energy sources.

The demand of economic policy makers, especially Western countries, to replace the use of fossil energy sources with solar and atomic energy, as well as greater use of biogas, energy from wind farms and electricity production using tidal energy is becoming more frequent. At the same time, there is a rationalization of the consumption of certain raw materials and reproductive material as a result of the use of robotics in industry, and there are also many forms of substitution of natural materials with artificial ones.

Technical progress is mostly incorporated into the production structure through investments in modernization, reconstruction, replacement and new construction.

Therefore, technological transformations, expressed in corresponding changes in the matrix of technical coefficients, are closely related to the structure of investments, so the effects of technical progress are manifested in changing the matrix of capital coefficients, which is an important part of dynamic intersectoral models.

This nature of the dissemination of technical progress must be matched by methods of updating cross-sectoral tables and anticipating changes in technical coefficients for the purposes of designing and harmonizing structural proportions.

3. METHODS OF UPDATING THE MATRIX OF TECHNICAL COEFFICIENTS

Different methods are used to update cross-sectoral tables, which are based on simplified assumptions about the simplified process of spreading technical progress in the production structure, i.e. that the dynamics of technical progress is the same in all production sectors of the national economy.

A group of Canadian authors, examining prediction errors based on the Canadian matrix of technical coefficients, proposed and empirically tested a fairly simple procedure for updating them, which assumes that all technical coefficients in one row of the matrix change in the same proportion as a result of the same dynamics of technical progress and substitution in all production sectors.

“By applying this procedure, the errors in predicting the values of technical coefficients have been significantly reduced, i.e the updated matrix of technical coefficients thus updated showed real production links much more accurately than the matrix of technical coefficients from the previous period."[1]

However, although prediction errors were significantly reduced by this method, it was never introduced into operational and practical application.

The designers of the economic growth model for the United Kingdom have developed a special method of updating the matrix of technical coefficients, known as the Biproportional or RAS method. This method in a more complex and accurate way reflects the processes and dynamics of technical progress in the production structure of the national economy.

This method also has the advantage that it enables the use of possibly available analytical information on the specifics and dynamics of technical progress in certain segments of the economic structure, and that in this way a more objective update of the matrix of technical coefficients is performed.

This method of updating the matrix of technical coefficients enables the prediction of changes in technical coefficients by entering assumptions about the type and dynamics of technical progress in a certain period - continuation of dynamics from the previous period or its acceleration or deceleration. However, we must note that this method cannot include specific individual breakthroughs of technical progress in individual sectors and individual enterprises in the national economy.

For the purpose of designing the economic structure by economic policy makers, it is necessary to separately anticipate and plan specific development of technical progress and huge changes in the application of technology in certain sectors and on that basis register such specific changes in appropriate values of technical coefficients. The bi-proportional (RAS) method of updating the matrix of technical coefficients provides great opportunities for this.

With adequate organized and coordinated activity of the highest governing bodies of the national economy and the participation of the bearers of the main economic activities, such a procedure is relatively easy to achieve. Numerous information can be used which is collected and analyzed in the preparation of certain aspects of economic

[1] Manne A. -"Applications of Input-Output Analysis", Amsterdam, 2013. year.

policy, as well as information on planned development plans, as well as on the plans of individual economic operators.

The practical feasibility of this procedure is so much easier because not all technical coefficients are needed for the formation of structural proportions of the national economy, but only their limited number of the most important ones.

Special attention is paid to these coefficients in the preparation of the matrix of technical coefficients for design purposes. It should be taken into account that changes in technical coefficients occur due to changes in the composition of individual sectors during economic development, and that changes can be predicted and assessed on the basis of individual development programs.

Therefore, combining methods that reflect the general trend of technical progress with individual analysis and planning changes in the leading technical coefficients can build an appropriate procedure for updating and adjusting the matrix of technical coefficients for designing structural proportions and planning economic policy. It should be borne in mind that in the complex process of preparing an economic policy strategy of particular interest may be the development of conditional structural projections based on the assumption that the updated matrix of technical coefficients from the base period remains unchanged.

Such a conditional projection provides a framework for systematic research and planning of expected changes in technology and the composition of individual sectors in the appropriate period.

"Also, empirical research by the group os Soviet autora is interesting; based on formulating a specific statistical model (‘Model of cross-sectoral mutual influencih’) they researched the factors of the production strukture which during the economic development causes certain changes in technical coefficeients, as well as changes in the structure of final consumption. They came to the conclusion that such a model can be applied in predicting the future economic structure.” [2]

In the analysis of the production structure of the economic system, there are a large number of technical coefficients that show production links of very low intensity and

[2] Granbeg A. -"Matematičeskije modeli socijalističejskoj ekonomiki", Ekonomika, Moskva, 2019. godine.

which, therefore, have an insignificant impact on the formation of structural proportions.

On the other hand, only a relatively limited number of coefficients show high-intensity production links, so first-class attention must be paid to these coefficients when designing structural proportions.

If these coefficients, which have a higher rank of importance for the formation of structural proportions, are grouped in a matrix of technical coefficients into separate blocks, then the construction of the model for design purposes can be significantly simplified.

Such an arrangement of higher-ranking coefficients would mean that production interdependencies within blocks are very intense and between blocks very weak. By neglecting the connections between the blocks, the entire production system could be treated as a set of approximately independent systems that could, therefore, be designed separately.

However, completely ignoring the links between the blocks would lead to errors in displaying structural proportions. Therefore, these connections can be integrated into the intersectoral model in an adequate and simplified way. In doing so, one can, for example, assume that deliveries of reproductive products from one block represent a certain empirically estimated proportion of the total production of the supplier sector or that they depend on the total production of the sector from the consumer block.

“The biproportional RAS method of updating the matrix of technical coefficients was developed in the early 1960s in Great Britain, which was used in the construction of the economic development model of this country.” The method is based on the assumption that the change of each technical coefficient in a certain time interval is a consequence of two simultaneous influences: substitution effects and fabrication effects"[3]

The substitution effect shows the extent to which an intermediate (reproductive) product, due to technical progress and other factors, is replaced by other products in the production system of the economy, ie the extent to which it replaces other intermediate products.

[3] Bacharach M. -"Biproportional Matrices and Input-Output Change", Cambridge 2010. year

The effect of fabrication shows the extent to which in a sector due to changes in technology and other factors changes the proportional share of material and primary inputs, that is, the value structure of its production.

The following example can be given to illustrate these effects. If, as a result of technical progress, plastic materials (sector i) replace wood in the intermediate consumption of individual sectors, and at the same time motor vehicles (sector j) become more complex requiring proportionally higher labor and capital expenditures, then we can expect that the technical coefficient a * ij from the earlier period, due to the effects of substitution, will increase, and due to the effects of fabrication will reduce.

It is the task of the method to estimate the magnitude of both effects in the form of substitution effect factors ri and fabrication effect factors sj with which to multiply the technical coefficient a*ij from the previous period to obtain an estimate of the new technical coefficient aij, resulting from the simultaneous influence of these effects.

$$aij = a^*ij\ ri\ sj$$

Ie for the entire matrix of the technical coefficients:

$$A = A^*\ ŕ\ ś$$

where ŕ and ś are diagonal matrixes with the elements ri i sj on the main diagonal.

The method is designed to require a minimum of basic information, namely:

- matrix of technical coefficients A * for an earlier (base) period, which we want to update to the current period and thus assess the new matrix of technical coefficients A, which we assume realistically reflects cross-sectoral relations formed in the current period,
- vector of total production of intermediate products “in” in the current period, which we can get if we subtract the vector of final consumption from the vector of total production X,
- the vector of total consumption of intermediate products “v” in the current period, which can be obtained if we subtract the vector of social product or value added from the vector of total production X.

Therefore, starting from the available matrix of technical coefficients A * for some earlier period, we have only the sums of rows of the matrix of intermediate (reproduction) consumption in the form of a vector - column “u”

$$u = \sum_{i=1}^{n} AX$$

and with the sums of the columns of intermediate (reproduction) consumption in the form of vector - order v

$$u = \sum_{i=1}^{n} AX$$

where X is a diagonal matrix with elements of the total production column X on the main diagonal.

In order to be able to estimate 2n technical coefficients on the basis of this 2n information (n = number of sectors), we must enter additional simplified assumptions about a certain uniformity of action of both effects.

These assumptions are:

- the substitution effect for an intermediate product and is the same for all consumers of that product, that is, all technical coefficients in the type and multiplied by the same substitution effect factor ri,
- also, the effect of the change in the degree of fabrication of sector j is the same in all material inputs of that sector, that is, all technical coefficients in column j are multiplied by the same factor of the effects of fabrication sj,

Thus, the estimation of the matrix of technical coefficients A consists in determining n substitution effect factors (r1, r2,........., rn) and fabrication effect factors (s1, s2,.........., sn). From the above, it can be concluded that the assessment of each technical coefficient is influenced by a different combination of factors r and s.

The main advantage of the RAS method is that it requires a minimum amount of information for the period for which the update and assessment of the matrix of technical coefficients is performed. Contrary to this advantage, its disadvantage is conditioned by the simplified assumptions on which it is based.

The reality of the results obtained by applying this method depends on the extent to which the effects of substitution and the effects of fabrication spread in a uniform way in the production structure of the economy, as well as whether they are the only or most significant cause of changes in technical coefficients.

"The first test of this method on the Belgian cross-sectoral table has already pointed out its shortcomings. The test was conducted in such a way that, using this method on the basis of the intersectoral table for 2010, the coefficients for 2016 were estimated.

After that, the obtained results were compared with the coefficients obtained from the originally made table for that year. Although most of the estimated coefficients did not show significant deviations from the actual ones, several more important coefficients showed significant deviations." [4]

The analysis identified three main causes of these deviations:

- The first cause was identified in the high degree of aggregation and generality of intersectoral tables, which is one of the known problems in some areas of application of input-output analysis, and can not be specifically attributed to the RAS method. Namely, if the processes of substitution and fabrication were uniform for certain already defined homogeneous production groups, by aggregating these groups into wider sectors, these processes can manifest themselves differently in individual consumer sectors.
- The second reason is in the assumption of uniformity of the process of substitution of a product in all sectors to consumers. If, for example, coal as an energy source is gradually replaced by oil, then this effect will not be reflected in the coke production sector as a consumer where coal serves as a raw material. Likewise, institutional and other factors can speed up or slow down the use of an input only in certain sectors, so these sectors will behave differently than average.
- The third cause arises from the very mechanism of the RAS method. If, namely, one element in the matrix of technical coefficients is evaluated too high, then all other elements in the same type or column must be evaluated too low, due to the given restrictions by rows and columns.

[4] Tilanus C. - "Input-Output Experiments", Rotterdam, Univ. Press, 2016. year.

It is obvious that the causes of possible deviations estimated from the real technical coefficients are specific for each economy and for each development period, so that the experiences from one case cannot be generalized.

However, we should point out the flexibility of the RAS method, because it can incorporate additional information that we have and thus improve the results we get from its application.

If, in addition to the minimum information required for the application of the RAS method for the year for which we perform the assessment, we have additional information or reliable estimates of individual cross-sectoral flows, then these flows can be exempted from restrictions and appropriate technical coefficients removed from the base matrix. remaining coefficients.

We then apply this modified RAS method only to estimate those coefficients for which we do not have any source information or reliable estimates. Ultimately, if we have source information or reliable estimates for a large number of cross-sectoral flows, especially important in the reproductive structure of the economy, then the modified RAS method provides a suitable instrument for adjusting all other coefficients for which we have no other adjustment options.

“From a practical point of view, two important points should be pointed out:

First, in the structure of the production system, as a rule, there is only a limited number of intersectoral flows that have a decisive influence on the formation of structural proportions and which, therefore, should be given special attention.

Secondly, additional source information or as reliable as possible independent assessments should be sought primarily for those cross-sectoral flows for which the knowledge of technological development in a given economy and a given period of time can be expected that the RAS method mechanism will not allow realistic assessment. “[5]

When the mentioned RAS method test performed such a procedure on the Belgian input-output table for several typical coefficients, a significant improvement of the general results and reduction of deviations (variances) estimated from the actual (real) coefficients was achieved.

[5] Tilanus C. - "Input-Output Experiments", Rotterdam, Univ. Press, 2015. year.

In this particular case, it was possible to include the actual intersectoral flows from the intersectoral table for those intersectoral flows for which the RAS method could not give satisfactory results.

Such a procedure is, of course, not possible to apply in practice, because we use the RAS method precisely because we do not have a cross-sectoral table made on the basis of real current data.

The modified RAS method is applied in the practice of updating and designing intersectoral tables. However, if a large number of intersectoral flows are presented on the basis of estimated parameters, as a rule, the problem of different degrees of reliability of individual estimates arises.

Changes in technical coefficients between the base year and the year for which the cross-sectoral table is being updated or designed are also due to changes in relative prices.

For the assessment of technical coefficients at the regional level, the RAS method is applied in two ways:

- to update the available matrix of technical coefficients from an earlier base period to the current period,
- to design the available matrix of technical coefficients of the entire national economy to the regional dimension, so that the matrix is brought in line with the limitations of regional production of intermediate (reproduction) products of each sector and the sum of consumption of intermediate products in each sector.

For the first method of application, the basic remarks that have already been made regarding the application of the RAS method at the level of the entire national economy are worth mentioning.

Previous tests of the second method of application have not shown particularly satisfactory results. The method could be successfully applied only in the case of a high degree of similarity of the production structure of the region with the production structure of the entire national economy.

In any case, the formation of intersectoral flows is specific to the economic structure of each particular region, so the results of individual tests cannot be generalized. The application of the modified RAS method in updating the matrix of technical coefficients certainly guarantees better results of estimating their value compared to other procedures.

CONCLUSION

To update cross-sectoral tables and matrices of technical coefficients, various methods are applied that are based on simplified assumptions about a simple and uniform and simplified process of technical progress in the production structure of the national economy.

The objectivity of the results obtained by applying these methods depends on the extent to which the effects of substitution and the effects of fabrication spread in a uniform way in the production structure of the economy, as well as whether they are the only cause of changes in technical coefficients in the observed period.

We can conclude that the objectivity of predicting the macroeconomic implications of investment decisions and thus the formation of a certain economic structure of the national economy using the intersectoral model of analysis depends on its ability to adequately determine the causes leading to changes in technical coefficients.

The practical feasibility of applying the Biproportional RAS method in updating the matrix of technical coefficients is easier compared to other methods because its application in the formation of structural proportions takes into account only a limited number of significant technical coefficients.

Special attention should be paid to these coefficients in the preparation of the matrix of technical coefficients for design purposes. It should be taken into account that changes in technical coefficients also occur due to changes in the production structure of individual market participants during the projection period.

Regardless of certain limitations assumed by the input-output analysis, it, with the use of appropriate and updated technical coefficients, represents a solid basis for realistic predictions of future economic flows of the national economy as well as predictions of its future economic structure.

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