Automation of Structural and Rank Analysis Methods in the Context of Digitalization of Social and Economic Processes

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Abstract

In the context of digitalization permeating all aspects of life, there is a growing demand for an effective monitoring tool to examine and evaluate economic development and accordingly make management decisions.

Based on the previous authors' accomplishments in the structural analysis of the economy and the developed computer program "The effective rank calculation of the objects according to the values of their parameter", this paper aims to combine two methods: structural analysis and the effective rank method to develop an algorithm of their automation and define the role of experts in using the methods. The proposed method of structural and rank analysis and automation of its application for governance objects: territorial entities, smart cities, sharing economy sectors can serve as a new tool to monitor and evaluate structural changes as well as to rank results of any rating.

The computer program "Structural and rank analysis" makes it possible:

- to monitor structural economic changes at the macro-, meso- , and micro levels;

- to identify the type of economy;

- to measure differences between similar objects in the typology or ranking;

- to predict future developments in service development and digitalization of the economy.

In the paper, the authors show the results of testing the method of structural and rank analysis considering a sample of economically advanced and developing countries as well as the evolution of the sharing economy across its sectors and activities.

Keywords: digitalization, structural and rank analysis methods, effective rank calculation, smart cities, sharing economy.

1. Introduction

Digitalization has become a basic trend for modern national economic systems. Digital technologies pervade all the areas: everyday life, activities of enterprises, governance. According to scholars, the digital revolution has impact and influences on all segments of society: consumers, producers, investors, exporters, importers, public policy makers, academics, students, consultants, administrators, lawmakers, and all others directly or indirectly involved in various processes of the new economy [1-3]. Prospects of digital society are dependent on the development and application

of smart computing and new technologies conducive to the economic development within national and local economic systems.

Trends of economic development at the national and regional level fit into patterns of structural change regarding service sector expansion and maximal automation of agrarian and industrial sectors to increase labor productivity and minimize losses caused by human factor – mistakes which can lead to economic losses and diminish the efficiency of an enterprise.

It is in line with the three-sector model by Clark-Fisher according to which the economic system evolution occurs in the following sequence: from agrarian to industrial economy, from industrial to service economy, from material to non-material (including financial and digital) services.

The traditional structural analysis of economic systems can be based on the classical proportion between 5 sectors of the economy: financial organizations, non-financial organizations, state administration, households, and non-profit institutions serving households. For international analysis and comparison of countries according to their economic development, UN-indicators are employed: amount of structural change, index of structural change, structural change speed, structural independence coefficient.

The algorithm of the structural analysis varies from the elementary part to whole ratio and factor analysis to international approaches to the structural analysis of national economic systems (see [4]; [5]; [6]). A similar situation prevails in the rank analysis where we can see a variety of approaches from simple sorting to distribution of population units as a result of various rankings (see [7] and [8]). More recent studies describe ranking methods such as the principal component analysis and the discrete rank method and propose a new method for functional data: the weighted local rank method (see [9]; [10] and [11]). There are also studies related to the application of the input-output model for structural analysis on the example of the agricultural sector [12]. Some scholars identify the relationship among variables whose reciprocal influence is not obvious and can go unnoticed even by specialists. [13]. Zarnowitz [14] and Tinbergen [15] present their attempts to measure and interpret structural changes and structural shifts.

A number of researchers ([16]; [17]; [18]) consider the problem of sufficiency and availability of databases to conduct the rank analysis. Based on this fact, we can highlight that one of the advantages of the proposed method is sufficiency and completeness of the United Nations and national statistics authorities' databases which allows an effective application of the method.

Structural and rank analysis is a popular research direction among Russian scholars. The authors based on the following studies: [19], [20], [21].

This paper seeks to describe a new tool which is a combination of the structural and rank analysis. The proposed method and automation of its application for governance objects: territorial entities, smart cities, sharing economy sectors can serve as a new tool to monitor and evaluate structural changes as well as to rank results of any rating.

2 Methods

The author's method of the structural analysis which is possible to be automated is based on the aggregation of the components of gross value added into three sectors: agrarian (D_A), industrial (D_I), and service sector (D_S) according to the three-sector model by Clark [22] and Fisher [23].

The algorithm for the application of this method is amenable to automation and does not require expert estimations of empirical results. It includes the following steps:

1) The database development .

For this purpose the UN-data is employed concerning division of gross value added into agriculture, hunting, forestry, fishing

(ISIC A-B), mining, manufacturing, utilities (ISIC C-E), construction (ISIC F) and service sector including wholesale, retail trade, restaurants and hotels (ISIC G-H), transport, storage and communication (ISIC I) and other activities (ISIC J-P) (The United Nations, 2017 [24]).

2) For each object of analysis (region, country, integration grouping of countries) the aggregation of gross value added components is conducted as follows:

 - the agrarian sector D_A includes ISIC A-B;

 - the industrial sector D_I includes ISIC C-E;

 - the service sector D_S comprises the components that are sequential in the gross value added structure: ISIC G-H, ISIC I and ISIC J-P.

 - ISIC F "Construction" is not included in these sectors but contributes to the construction of the additional structural analysis indicator – D_G encompassing all the goods produced within the national or regional economy.

3) The indicators are calculated correlating D_A, D_I и D_S as follows:

$$k_\alpha = D_I/D_A; \tag{1}$$

$$k_\beta = D_S/D_I; \tag{2}$$

If we coordinate mining and manufacturing within the industrial sector and distinguish material and non-material services within the service sector, we can go the next hierarchical level of the structural analysis detailing trends and quality of industrialization and servitization within the economic system:

$$k_v = D_O / D_D; \qquad (3)$$

$$k_\mu = D_{NMU} / D_{MU}. \qquad (4)$$

where D_D – ISIC C «Mining»

D_O – ISICD «Manufacturing»

D_{MU} – ISIC G, H, I

D_{NMU} – ISIC J, K, N, O.

4) Based on the characteristics of k_i values obtained that interpret and classify the examined economic system as a certain type of development (See Table 1.), we receive a distribution of economic systems into groups. Limit values of k_i on the basis of which the distribution will occur may be changed by the experts according to the data k_i obtained.

Table1. Matrix of economic systems complied according to the intersectoral proportions of k_i

Intersectoral proportions (stages of economic development)		According to the economy sector – Metatype – industrial and commodity-oriented			
		$D_A > D_I$ (agrarian type)	$D_I > D_A$ (industrial type)	*Including*	
				$D_D > D_O$	$D_O > D_D$
According to the economy sector – Metatype – commodity and service-oriented	$D_I > D_S$ (commodity-oriented economy)	**1 Type agrarian**	**2 Type industrial**	Subtype: commodity-oriented industrial	Subtype: developed industrial
	$D_S > D_I$ (service-oriented economy)	**3 Type service-agrarian**	**4 Type service-industrial**		
	Includes:				
	$D_{NU} > D_{MU}$ \ $D_{MU} > D_{NU}$				
	Subtype: developed service-oriented \ Subtype: material - service-oriented				

The quantitative distribution is complemented by the graphic analysis when using the example of k_α and k_β, evolution trajectories of economic systems are built on the dot plot over a certain period with the identification of a common vector. (See the example in Figure 1).
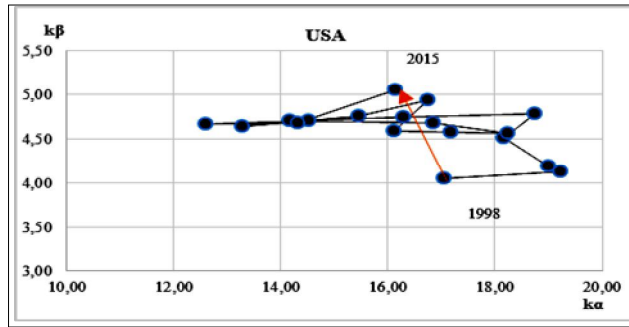
Fig. 1: Graphic representation of the k_α and k_β correlation using the example of the USA economy for 1998-2015

Figure 2 shows the example of the distribution of countries on the graphic field presenting the typology of the economic systems according to their structure.
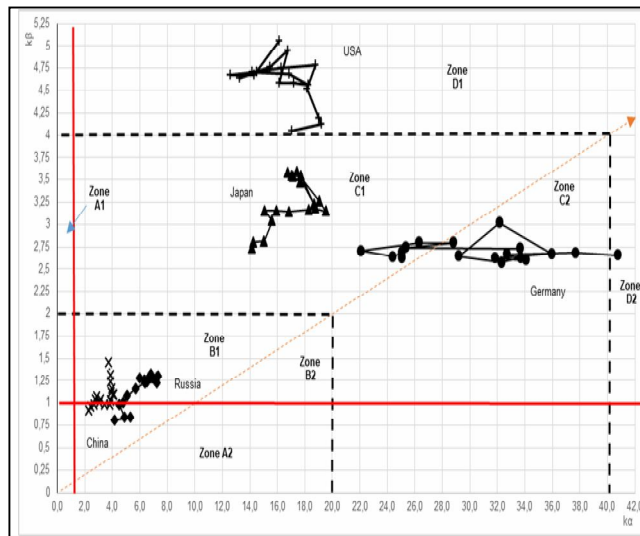
Fig.2: The graphic field division into zones reflecting the results of structural changes to provide a typology of the economy using k_α and k_β

Source: compiled by the authors based on the method of the structural analysis according to the United Nations data «Gross value added (GVA) by economic activity at current basic prices».

The typology was prepared based on the empirical analysis and shows quantitative boundaries of the following graphic field zones: zero zone (values k_α and k_β are less than 1), zones A, B, C and D with the additional internal sub-division. The detailed characteristics of the zones are presented in Table 2.

A similar internal sub-division can also be applied for the calculated values of the additional indicators k_v and k_μ. For justification of the authors' interpretations, the matrix of economic systems complied according to the intersectoral proportions was employed (Table 2).

Table 2. The first level of the typology for economic systems on the basis of the structural analysis and identified zones

Type (sector) designation	Conditions of structural changes	Type interpretation
Zone 0 - typical for the least economically developed territories		
Zero zone	k_α and $k_\beta<1$	Agrarian type is typical for the economically backward territories
Zone A – typical for the economically underdeveloped territories		
Zone A1	$k_\alpha<1$ $k_\beta>1$	Agrarian-service type is typical for the economically underdeveloped territories
Zone A2	$k_\alpha>1$ $k_\beta<1$	Industrial type
Zone B – typical for the territories with the steadily growing economy		
Zone B1	$1<k_\alpha<20$ $1<k_\beta<2$	Less developed service-industrial type where the development of the service sector prevails over goods production
Zone B2	$10<k_\alpha<20$ $1<k_\beta<2$	Developed industrial type
Zone C – typical for the territories with the highly developed economy		

| Type (sector) designation	Conditions of structural changes	Type interpretation
Zone C1	$1 < k_\alpha < 40$ $2 < k_\beta < 4$	Service-industrial type is typical for the economically developed territories with the priority for service expansion
Zone C2	$20 < k_\alpha < 40$ $1 < k_\beta < 4$	Industrial-service type is more developed in comparison with the zone C1
Zone D – typical for the territories with the most intensive and sustainable economic development		
Zone D1	$1 < k_\alpha < 60$ $4 < k_\beta < 6$	The most developed service-industrial type defining a vector in the future economic development
Zone D2	$40 < k_\alpha < 60$ $1 < k_\beta < 6$	The most developed industrial-service type following the zone D1

Monitoring of the transition from one type (or sub-type) of the economic system to another makes it possible to evaluate the quality of structural changes and public economic policy in this area. Tracking the structural shifts will provide data on the results of economic policy.

The only difficult step in the automation of the presented structural analysis algorithm is in applying expert estimates for the assignment of an economic system to one of the zones based on the graphic analysis and zones typology. Boundaries of k_i values can change depending on the empirical data in the analyzed population.

3 Results

The traditional development from the agrarian sector to the service sector according to the proportion DS>DI>DA has already successfully been tested. New developments and results of applying the structural analysis can be presented using the example of sharing economy. According to the recent studies (see [25]; [26]; [27]) the sharing economy comprises the following sectors: transportation services; accommodation, rental and office sharing; crowdfunding (co-funding); C2Csales; rental of goods; P2P services (freelance) and B2B introduction rental.

The authors aggregated the sharing economy sectors into D_i applying the Fisher-Clark theory of structural change and based on the premise that economic development evolves towards the complexity: in this case from the C2C sector to the sector "Co-funding" and "B2B" (figure 3).
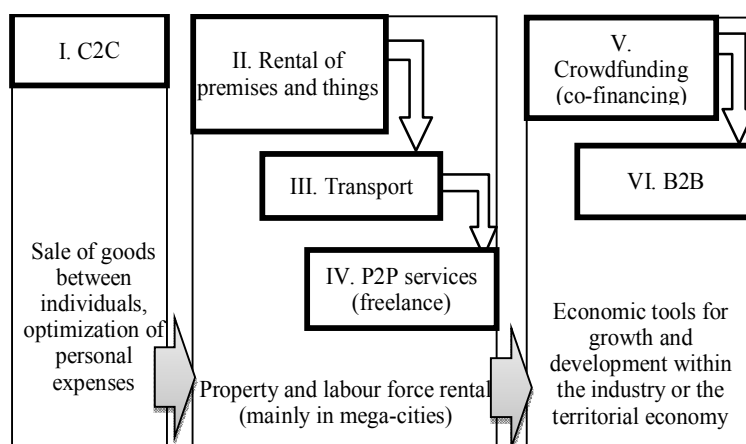
Fig.3: Transition between the sharing economy sectors in the context of increasing scientific and technological progress and complicating social and economic connections and ties

Source: compiled by the authors

As a result, the following indicator values D_i have been identified:

-D_1 includes only sector1 - C2C;

- D_2 includes the sectors 2, 3 and 4;

- D_3 includes the sectors 5 and 6.

The relationship between the aggregated sharing economy sectors is a framework for measuring structural ratios of their changes. The formulas (1) and (2) were applied as follows:

$$k_\alpha = D_2 / D_1; \qquad\qquad (5)$$

$$k_\beta = D_3 / D_2. \qquad\qquad (6)$$

Employing the database on the capacity and development of the sharing economy sectors in the Russian Federation for the years 2017 and 2018 (see Table 3), the authors made the necessary calculations (Table 4) and received the following results:

Table 3: Volume development indicators of the sharing economy sectors for 2017-2018

Sectors of the sharing economy	Units of Measurement	2017		2018	
		Number of services	*Amount of transactions, mln. rub.*	*Number of services*	*Amount of transactions, mln. rub.*
I.C2C sale	Number of transactions, mln.	90	295000	116	370000
II. Rental of premises and things					
2.1. Short term rental of accommodation facilities	Number of guests, mln	1,2	5800	1,6	9800
2.2. Officesharing					
- co-working	-	-	2600	-	3500
- ready offices (OaaS)	-	-	1700	-	2200
2.3.Rent of things	Number of transactions, thous.	25	80	60	180
III. Transport:					
3.1. Car-sharing	Number of trips, mln	12	5100	37	13000
3.2. Carpooling	Number of trips, mln	24	8100	39	13700
IV. P2P services (freelance)	Number of transactions, mln.	49	73000	64	98000
V. Crowdfunding (co-financing)	number of fundraising campaigns, units	1020	300	1333	400

Source: compiled by the authors based on the material of the Russian Association of Electronic Communications (2018) [28].

- the highest increase within the aggregated sectors for the years 2017 and 2018 can be seen in the accommodation rental and rental of labor force; the growth of k_α is indicative of development trends in the sharing economy of the Russian Federation;

- regarding the prospects of the sharing economy in the coming years and decades the aggregated sector D_3 which includes crowdfunding and B2B (premises and other funds rental among companies) is considered to be the most important and complicated in terms of growth; the received indicator k_β shows the necessity to institutionalize rules and conditions of the sharing economy practices particularly with regard to security issues and transparency in transactions.

Table 4: Results of the structural analysis of the sharing economy in the Russian Federation for the years 2017 and 2018

Indicators	2017	2018	Interpretation
D_1 (mln. RUB)	295000	370000	The best developed, extensive and core sharing economy sector with a 25,4 percent growth rate for one year.
D_2 (mln. RUB.)	96380	140380	All the sharing economy rentals are accumulated in this sector. The proportion should be : $D_2 > D_1$ The largest growth within this segment was 45,7 percent for one year.
D_3 (mln. RUB)	300	400	The most economically relevant sharing economy segment. In the sharing economy evolution it must exceed D_2.
$k_\alpha = D_2 / D_1$	0,33	0,38	Normative value: $k_\alpha > 1$ k_α has grown by 16,1 per cent
$k_\beta = D_3 / D_2$	0,00311	0,00285	Normative value: $k_\beta > 1$ k_β has decreased by 8,5 per cent

According to the calculated indicators k_α and k_β for the period of time which makes it possible to analyze and evaluate trends, a graphic field can be built to investigate a national economy or several national economies with the aim to compare them. The evolution vector for the analyzed period is evaluated empirically and the quality of changes within a national economy or in its regions or cities analyzed.

The authors of the study conclude that the more the indicators t_α and t_β exceed1, the more developed the economy can be considered according to its structural changes for the analyzed period. Consequently, it can be characterized as the economy with well-developed industrial and service sectors.

Based on the received data, it is possible to mark more points on the graph, but there is a limitation related to a lack of data on the structure and dynamics of the sharing economy in different countries. The interpretation of the graph will be identical to the presented in Figure 2 correlation field.

The calculations of the structural analysis indicators allow one to identify an exact development vector for the sharing economy and to justify the need for developing a digital, legal and ideological base to ensure the increase in the rate of evolution according to the target vector: to the growth of aggregated shares of D_2 and D_3in comparison with D_1.

The authors compared each sector of sharing economy with the previous one and found out that the proportion of sharing economy in the overall economic activity at the current stage must be greater than at the previous stage: $D_3 > D_2 > D_1$. In practice, this proportion does not always work. However, it makes possible to distinguish the development level of the sharing economy in different countries. If the condition is met, the country can be considered well-developed. If the condition is not met, the country is indicated as less developed.

After presenting and processing the results of k_i calculation it is necessary to continue the analysis as a part of the method. The dependence of the rank analysis on the structural analysis is in the bund to the k_i values and in the received zones typology (Figure 2, Table 2).

If we consider the method of the rank analysis (the effective rank method) as a distinct approach to ranking, it can be applied separately from the structural analysis.

The presented algorithm of the rank analysis was partly patented in Russia [29]; the authors propose to develop the patented results in the following way:

1) For the purpose of ranking, it is necessary to organize the objects of the structural analysis according to the calculated k_i

values in ascending order (for example, according to the k_α values).

2) In the developed database of the ranked objects, a section of the linear trend is determined built according to the equally changing values of the indicators included in the rating (with the maximum value of the determination coefficient of R2).

3) The next stage of the rank calculation algorithm and objects distribution is the calculation system including the following steps:

- the variation scope for the selected indicator is calculated, for example, the maximum and minimum profit value for agricultural enterprises:

$$R = x_{max} - x_{min} ; \tag{7}$$

- the linear rank distribution is modeled:

$$LRD = x_{min} + (i - 1)*h , \tag{8}$$

where $i = 1,…, n$ – rank r of the ranking object (certain regions or countries);

$h = R/ (n-1)$.

- isomorphic mapping of the non-linear value structure is built for the indicator selected for ranking in the corresponding structure of positive integers:

$$Y = k \times r + a_0, \tag{9}$$

where Y is the ranked indicator;

k is the linear coefficient;

r is rank of the region;

a_0 – an absolute term.

- by substituting empirical values of rank indicator instead of Y to the ₚᵣₑₛₑₙₜₑ𝒹 equation and by solving it according to the rank r, we have the following expression:

$$r = \operatorname{int} eger[\frac{y - a_0}{k}],\qquad(10)$$

where integer (argument) is a function rounding off its argument to the closest smallest integer value.

The formula $Y = k \times r + a_0$ is transformed to the formula for the calculation of the effective rank r^*, where parameters of the equation of straight line calculated along a linear segment are used instead of k and a_0.

- An additional procedure for building effective rank values for all the rank units is a displacement of maximum rank to the value 1.

- Typology of ranked objects to ensure the most correct distribution and interpretation of ranking results. This requires taking into account the results of objects typology according to the data of the structural analysis and assignment to a certain type.

A difference in the level of economic development within various territories is dependent on such important factors as population density, size of the territory, investment attractiveness of certain sectors of the economy. It requires a preliminary typology of ranked objects according to the similar economic development areas (table 5) and establishing a hierarchy of effective rank levels (figure 4).

Table 5. Results of the preliminary regions typology in the Russian Federation for ranking purposes

Type no.	Characteristic of economic development area	Assignment of the territory to a certain zone
I type	The territories have leading positions in the financial, cultural, tourist, and social development	Zones D and C
II type	Territories have a highly developed industry, high population density, and the severe environmental situation	Zone B
III type	Commodity economy against low population density and difficult climatic conditions	Zone A2
IV type	Agrarian economy against high population density and good climatic conditions	Zone A1
V type	Highly subsidized territories with underdeveloped economy	Zero Zone

Figure 4 shows the example of objects ranking according to five identified types. This approach takes into consideration the

differentiation of regions in the Russian Federation according to the type of economy and is more exact in comparison with general ranking.
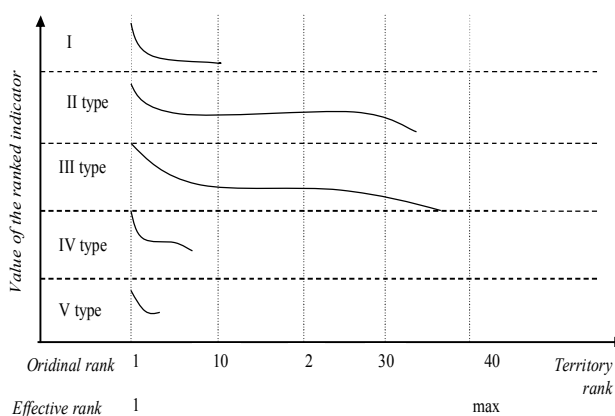
Fig.4.: Multi-level ranking of the regions in the Russian Federation according to the type of the economic system

4   Conclusion

The results of testing the method of the structural and rank analysis make it possible to evaluate the economic systems with different structure and level of development as well as to see the place a certain territory takes among other ranked objects.

The use of this method opens new prospects for testing territories or enterprises to identify the achieved level of development, evaluate the quality of management, and prospects

for further development management in accordance with strategic objectives.

Feasibility of automation of database processing and receiving the results of the method according to various indicators of the economic development is limited only to the expert decisions across the limits of values of k_i.

In order to implement this method as a software product, the following steps are recommended. First, it can be used as a tool of a think tank or an expert group cooperating with governments. Then it is necessary to organize training sessions on applying the method and interpretation of its results. Finally, the method should be adopted by governments to measure and monitor the economic developments of the territory or management units.

5　Acknowledgments

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