

Intersectorial Structure of National Economy: Algorithm for Studying Industrialization Rate

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Abstract — The sectoral structural theory of national economy by Clark-Fisher is based on the hypothesis that a gradual redistribution of production of the highest GVA value from the agrarian to the industrial sectors and then to the service sector occurs in the course of social evolution. The authors of the paper present their achievements in studying industrialization and servicing rates of economy while taking into account, firstly, the tendency of non-material services and manufacturing industries increase in the regional economic intersectoral structure; secondly, the need to develop methodological basis for analyzing intersectoral structure of economies of any scale. We applied new typology which allows not only to evaluate and compare the achieved level of economic development of a particular territory, but also to underline priorities of economic policy in digitalization, industrial revolution and introduction of “industrial Internet” into public strategic regulations. The principal conclusions drawn by the authors of the paper are the following one: national economy can be presented as a superposition of various types of mesoeconomies at the appropriate levels of its decomposition; each mesoeconomic type can be quantitatively characterized by the degree of evolutionary development of the intersectoral structure and its developmental vector in the area of indicators of industrialization and service economy development rates at each level of the hierarchy of national economy.

Keywords— *Industry 4.0; digitalization; hierarchy; typology; disaggregation; industrialization; service economy; intersectoral evolution.*

I. INTRODUCTION

If economic development is referred to as evolution of a system that is irreversible and requires the formation of interrelated institutions with sustainable intersectoral financial ties, movement of resources, including labor resources, then the value of structural analysis for developing appropriate economic policy to manage this development is high and requires universal analytical tools ensuring comparability of data in time and space for research and practical needs.

We take into account the western trend of the fourth phase of industrial revolution “Industry 4.0” and the idea of merging technologies (combining physical, biological, digital spheres) to increase the competitiveness of national economies (using Germany as an example) through enhanced integration of “cyber and physical systems” (CPS) into industrial processes and the ideas of “Service-oriented design” when users can apply manufacturing settings to produce their own products or companies supply customized products to individuals (“industrial Internet”).

However, classical interpretation of the economic system evolution confirms the universality of the authors' application of coordination indicators for analyzing intersectoral proportions and their modifications and allows to move to a new level of research in this area that is to develop a universal typology of the economic system. The typology is capable of classifying any territories according to intersectoral proportions and can be applied for managing their development through effective public structural economic policy.

Another argument in favor of the growing interest to and understanding of the importance of research in intersectoral structure and its dynamics is confirmed by the expert assessment results of modern crises on both global and national scales: "... universal government policy which is based only on macroeconomic theory is not always successful. The main disadvantage of this theory is that it cannot predict crises"[1].

Systematic approach to the study of economies of different scales (from global to micro levels) implies its social and economic structural analysis. The authors of this paper are of the opinion that the system structure is a complex set of relations between elements of the system, and if its composition can vary, the integrity of the economic system and its purpose is preserved. According to interpretations by Clark and other researchers, the formed intersectoral structure of GVA determines the degree of evolutionary development of the studied economy ([2]; [3]; [4]; [5]; [6]; [7] and [8], [9]). Conclusions drawn by [9] and [10] show that interdisciplinary structural analysis of GVA (gross value added) at various levels of national economic hierarchy allows to conduct statistical study of intersectoral proportional dynamics. Therefore, in this paper, the GVA and its structural characteristics are used as a grouping feature to design the appropriate typology.

II. GDP AGGREGATION AND DISAGGREGATION METHODS

A. GDP Aggregation at the meso level

Disaggregation of GDP by any feature leads to a structural analysis of national economy. Further disaggregation of the GDP components will lead to the formation of new meso-levels and corresponding economic entities (fig.1). Such a procedure can formally continue up to the classical level of microeconomy.

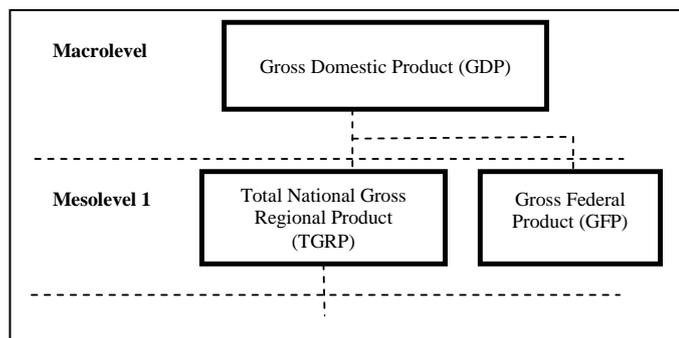


Fig. 1. An example of disaggregation of GDP at the meso level of the first level

The main share of GDP in many countries is created in regions (over 80% for the Russian Federation). Therefore, the state of the national economy and its dynamics are determined by production of GVA in regions, that is the by the total gross regional product (TGRP) for a given country. The remaining part of GDP which is formed by federal supra-regional structures is designated as Gross Federal Product

(GFP). Mesolevel 1 is formed in the result of the GDP decomposition into TGRP and GFP. Since one of the objectives of the typology creation is analysis of inter-sectoral proportions` evolution up to the regional level, further typologization of mesoeconomic types is done through disaggregation of TGRP by economic activity.

GVA is formed at micro economic level and due to aggregation becomes statistically observable and widely accessible to researchers at the municipal, regional and national levels. Aggregation is carried out with regard to territorial and administrative features by the relevant types of economic activity (TEA). Aggregation of regional GVA with different sectoral structure leads to an increase in the heterogeneity of statistical data. Due to data heterogeneity their further analysis is feasible only at the macro level, since the data is aggregated for regions belonging to different types of economic systems. The system approach includes the decomposition of national economies "from top to bottom." Such an approach allows designing various hierarchical typologies of economic systems of various levels of national economy decomposition. The selection of typology and of corresponding grouping feature is determined by the purpose of the study.

In order to study structural dynamics of economy and its relationship to economic growth quality, a number of reseachers use the Clark-Fisher approach based on disaggregating the GVA indicator by sectors of the economy ([4]; [9]; [10]). The sectoral approach by Clark-Fisher reflects the trends and priorities of economic development and is based on a three-sectoral model of the economy. According to Clark-Fisher, the evolution is refferred to as transition from one priority economic sector to another in accordance with the changing technological capabilities of economic activity, mass production pace, improved consumers` quality of life, social safety and comfort of living in modern social and economic conditions. Based on the content of this approach, it can be argued that the study of the evolutionary trajectory of production development of the entire national or regional economy is based on aggregating parts of gross value added as follows:

- firstly, the agriculture sector is formed accompanied by automation increase and decline of the sector in the share in gross value added, in GDP or GRP;
- secondly, industrial sector is characterized by higher labor productivity and its own evolutionary development; its predominance over the agricultural sector in the structure of the economy indicates a higher level of development in the chosen trajectory which is accompanied by progress in scientific and technical spheres or was the result of an active colonial policy at the era of globalization of the world market;
- thirdly, the service sector is the most developed and highly profitable area of economic activity, its division into the material and non-material services sector underlines evolutionary trajectory and covers different types and levels of economic development at the post-industrial stage.

It can be stipulated that such trends were institutionalized in the current research practice and are

expressed in the accepted norms of identification of national economies as economically developing or economically developed, both in formal and informal norms and regulations. The common practice in the standards and criteria applied for assessing economic development of the world economies include patterns of economic development based on the principle of changing intersectoral priorities in the direction of the increasing industrial production followed by growing service sector in particular non-material services. In this paper, in order to study intersectoral structural dynamics of the national economies on the example of the Russian Federation and a number of other countries, and of the subjects of the Russian Federation at the mesolevel, we suggest applying the author's approach to structural analysis which is fundamentally different from the common used one in particular from UN practices. The standard system of indicators for conducting structural analysis of national economies includes such indicators as structural shift mass (difference in the share of the structural indicator in the current P_1 and in the base P_0 periods); structural shift index (as the ratio of the sum of the difference in the share of growing sectors in production, employment, investment at some point in time and at the initial moment of time to the number of growing sectors multiplied by the total duration of time); the rate of structural shift (the ratio of the mass of the structural shift to the time during which it occurs); coefficient of structural independence (the ratio of exports to imports).

The author's approach to conducting an evolutionary-statistical study of the dynamics of the inter-branch structure of the national economy is based on the following conditions and order:

- we apply classification of the sectoral structure of gross value added (GVA) traditional for macrostatistics, national accounts which includes the division of GVA into 15 sections, starting with section A "Agriculture" and ending with section P "Household activities" (according to Russian Federal State Statistics Service over 2016);

- aggregation of the elements composing GVA is carried out according to the following scheme:

- 1) agricultural sector (D_a) includes sections A and B (fishing, fish farming);

- 2) industrial sector (D_i) includes the following three sections in the structure of the GVA; including C "Mining", D "Manufacturing production" and E "Production and distribution of electricity, gas and water";

- 3) service sector (D_s) consists of ten subsections which come in sequence in the structure of the GVA starting from section G "Wholesale, retailing, maintenance, etc." and ending with section P.

It should be clarified that Section F "Construction" is not included in any of the above presented sectors but is present in another additional indicator of our analysis D_g which accumulates in itself all goods produced within the national or regional economy.

- the study of the intersectoral structure of regional economic systems using coordination indices allows using two structural characteristics to describe these systems:

$$\alpha = D_i / D_a \tag{1}$$

$$\beta = D_s / D_i \tag{2}$$

Indices, or relative indicators of coordination, are used in statistics to quantitatively characterize the structure of economic phenomena. The coordination index shows the quantitative ratio between the parts of the aggregate (the whole), or how many units of one part fall on one unit of another, taken as the base of comparison.

The degree of industrialization of α shows how many per unit of GVA created in agricultural sectors account for such units created in industry. For the first time, a similar approach to structural analysis was presented in [4]. In the course of the study, it was determined that the more basic α and β values exceed 1, the more economically developed will be the economy according to its structural changes over the period and, accordingly, characterized as an economy with developed industrial and service sectors.

B. Assessment of the level of industrialization of national economies

Applying the theory of intersectoral structural changes of Clark-Fisher ([2]; [3]), the evolution of α and β , we analyze the corresponding structural changes in the economies of China, Germany and Russia. At the macroeconomic level, China is currently characterized by the largest volume of the national economy (GDP), followed by Germany and Russia in order. In order to characterize the "quality" of the volume or growth of the national economy, it is necessary to examine its sectoral structure at the meso-level 3 (Fig. 2).

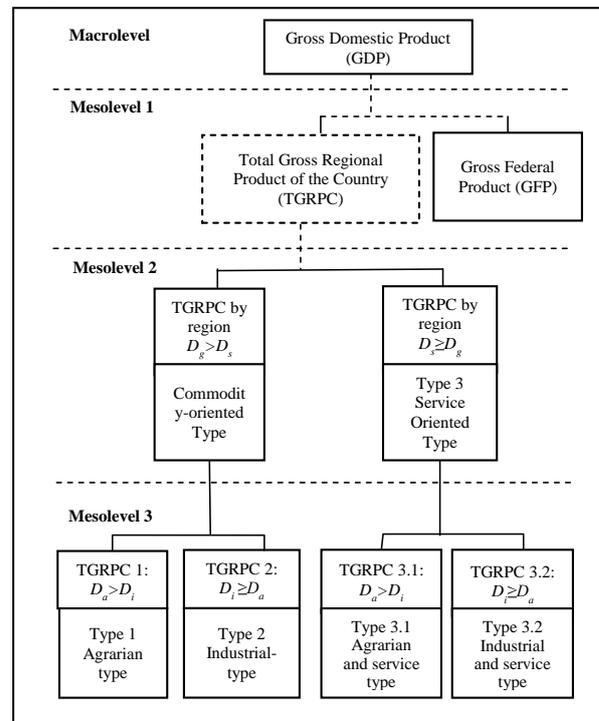
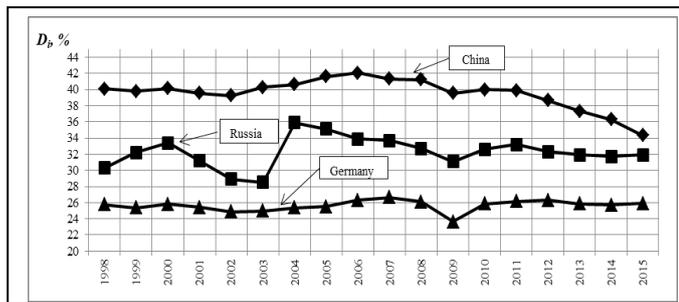


Fig. 2. Variety of GDP disaggregation at the meso-level

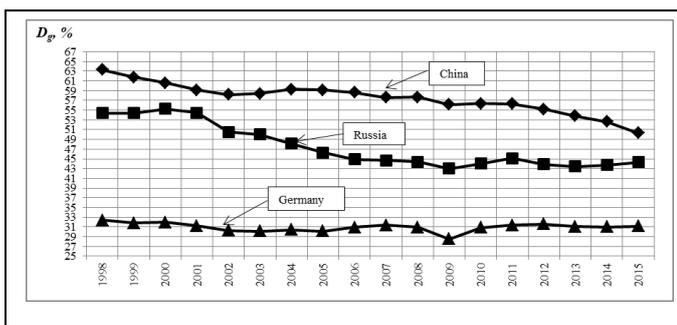
The dynamics of the sectoral structure of the economies of these countries for 1998-2015. is presented in fig. 3. According to the three-sector Clark-Fisher model, the

most evolutionary developed economy of these three countries is the economy of Germany, since its sectoral structure satisfies the condition: $D_a < D_i < D_s$ and the value of D_s for Germany significantly exceeds this value for Russia.

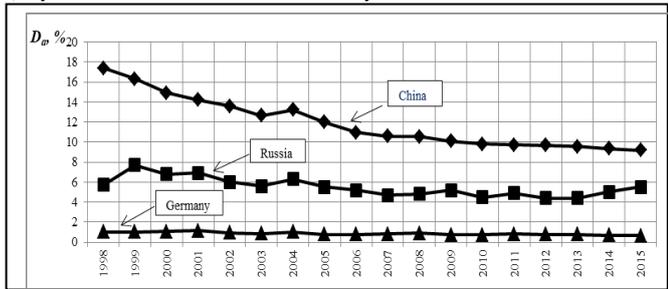
a) Dynamics of the share of the agricultural sector in the structure of the GVA



b) The dynamics of the share of the industrial sector in the structure of the GVA



c) Dynamics of the share of the commodity sector in the structure of GVA



d) The dynamics of the share of the service sector in the structure of GVA

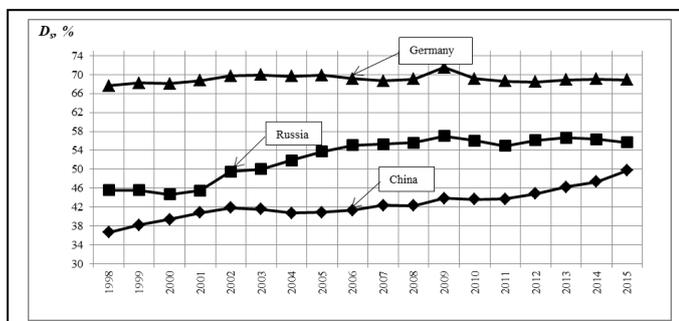


Fig. 3. The change in the specific weights of the sectors of the economy Di Russia, China and Germany in the structure of gross value added (GVA) for 1998-2015

Source: compiled by the authors according to Rosstat "Sectoral structure of gross value added of the subjects of the Russian Federation" and the United Nations "Gross value added (GVA) by economic activity at current basic prices"

The results of the structural analysis of the data economies of 3 countries are presented in table 1. First of all, we give a description of the evolution of the structure of the German economy, the largest and most effectively developing among other EU countries and the world:

- the type of the economic system of Germany can be defined as industrial-service type 3.2 at the meso-level 3, at which $D_i > D_a$ during the entire analyzed period, while in 1998 for every 1 monetary unit of agricultural production there were 25.1 monetary units produced in (degree of industrialization $t_\alpha = 25.1$), then by 2015 the situation had changed significantly: the ratio $D_i > D_a$ was 25.92% to 0.64% ($t_\alpha = 40.8$, see Fig. 3c). With a reduction in the share of agriculture D_a by almost 2 times, a slight increase in the share of industrial production D_i in the GVA led to an increase in the level of industrialization of the country's economy by 62.5% from 1998-2015.;

TABLE I. RESULTS OF THE STRUCTURAL ANALYSIS OF THE ECONOMICS OF GERMANY, RUSSIA AND CHINA

Country	1998	2015	Features of economic development results
Germany	$D_i > D_a$ 25,1 times ($t_\alpha = 25,1$) $D_s > D_g$ 2,1 times	$D_i > D_a$ 40,8 times ($t_\alpha = 40,8$) $D_s > D_g$ 2,2 paza	Industrial and Service type 3.2 with a high level of development of industrial and service sectors
Russia	$D_i > D_a$ 5,3 times ($t_\alpha = 5,3$) $D_s > D_g$ 1,2 times	$D_i > D_a$ 5,8 times ($t_\alpha = 5,8$) $D_s > D_g$ 1,3 times	Industrial and Service type 3.2 with low rate of industrial and service sectors` development
China	$D_i > D_a$ 2,3 times ($t_\alpha = 2,3$) $D_s > D_g$ ($t_\beta = 0,6$)	$D_i > D_a$ 3,7 times ($t_\alpha = 3,7$) $D_s > D_g$ ($t_\beta = 0,99$)	Industrial type 2 with actively developing sectors of industry and services

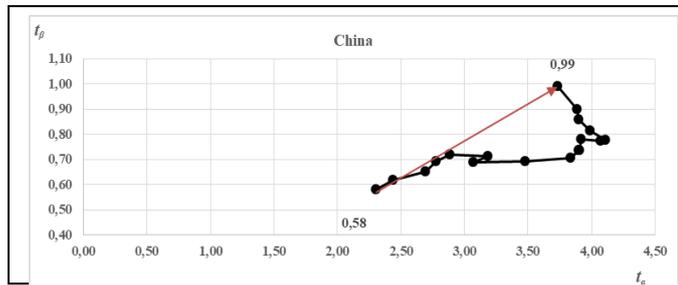
- when the sectors of the German economy are enlarged to the spheres of production at the meso-level 2, the economy of this country belongs to service-oriented type 3: $D_s > D_g$. In 1998, the share of the production of services in the GVA of the country was 2 times higher than that of the production of goods. By 2015, the ratio did not change significantly, and was 2.2 times, indicating a stable economic development of Germany in the context of the global financial crisis, the effects of sanctions and the threat of rising fuel prices for industry and the population. The degree of Germanization of the t_β economy or the relative development of the services sector (Type 3.2) relative to the industrial sector also exhibits stable behavior, experiencing small fluctuations mainly in the 2.2-2.3 range.

III. INTERPRETATION OF THE MESOECONOMIC STRUCTURE OF NATIONAL ECONOMIES

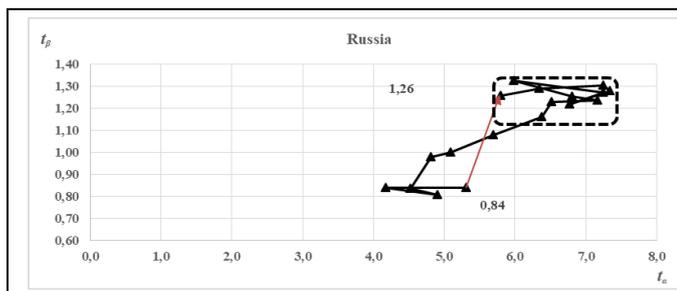
As follows from the above analysis, the use of structural indicators t_α and t_β allows not only quantitatively characterize the degree of evolutionary development of one

mesoeconomic subsystem in relation to another (for example, economic sectors), but also to present their joint evolutionary development trajectory in the space of these indicators. Such trajectories are presented for Germany, Russia and China in fig. 4, where the dotted line indicates the area of structural fluctuations, which will be discussed later in the article.

a) structural dynamics in the space of $t\alpha$ and $t\beta$ at the meso-level 3 on the example of China



b) structural dynamics in the space of indicators $t\alpha$ and $t\beta$ at the meso-level 3 on the example of Russia



c) structural dynamics in the space of indicators $t\alpha$ and $t\beta$ at the meso-level 3 on the example of Germany

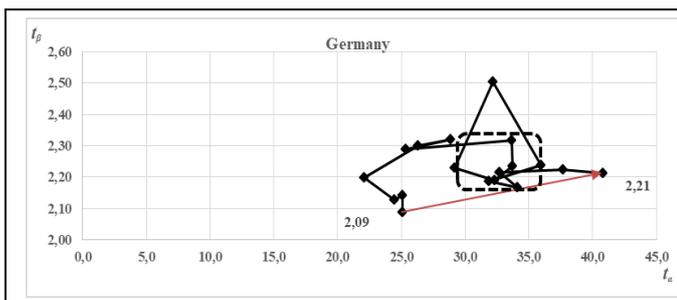


Fig. 4. Structural dynamics in the space of $t\alpha$ and $t\beta$ indicators at the meso-level 3 for the analyzed group of countries for 1998-2015.

Source: compiled by the authors according to Rosstat "Sectoral structure of gross value added of the subjects of the Russian Federation" and the United Nations "Gross value added (GVA) by economic activity at current basic prices"

Decomposition of the national economy into spheres, sectors, foreign economic activity, etc. supported by various institutions through appropriate organizational structures. Therefore, various hierarchical typologies indirectly reflect the institutional nature of the organization of national economies. Some authors believe that economic systems operate within the framework of institutional matrices (Kirdin-Chandler SG and co-authors). Thus, a priori, the production of GVA occurs

in certain institutional conditions, which can be indirectly reflected in the respective typologies.

By aggregating the values of the grouping attribute of the regions belonging to the same mesoeconomic type, the new economic entity ("macro-region") is essentially determined. The national economy can be considered as a superposition of various types of mesoeconomics at a given level of its decomposition. In the spatial-territorial representation, each type of mesoeconomy will correspond to the geographical location of real regions included in this mesoeconomic type. These regions may not have common territorial borders within the framework of one national economy and alternate with regions through which another type of mesoeconomy of the same level of decomposition is realized.

The characteristic of the mesoeconomic structure of the national economy will make it possible to determine the level of its evolutionary development and its vector. To evaluate the quality of economic growth in comparison with other countries, to form the structural policy of the state.

Quantitatively, the level of industrial development of a country or region can be measured using a structural indicator such as $t\alpha$, which was previously determined (formula 1). This indicator can be considered as a quantitative characteristic of the degree of evolutionary development of the economic system within the boundaries of the type of mesoeconomy under consideration.

If $t\alpha = D_i / D_a < 1$, then the economic system can be unambiguously attributed to the agrarian type 1. As the study of the authors shows, the possible values of $t\alpha$ can be characterized by a large range of variation and heterogeneity, especially for countries consisting of a large number of territorial-administrative units.

Based on the principle of minimal definition of new types, facilitating their meaningful interpretation, using cluster analysis or other grouping methods in the typology proposed in this work, each type of economy corresponding to the meso-level 3 is decomposed into a weakly industrial, middle industrial, and highly industrial type.

Analysis of the structural dynamics of the Russian economy at the meso level 1 shows that for the period 2006-2016. the average degree of industrialization in all its regions decreased by 9.2% and amounted to $\langle t\alpha \rangle = 5.9$ in 2016. The degree of service, on the contrary, increased by 11.2% and in the same year amounted to $\langle t\beta \rangle = 1.8$. According to the values of the structural indicators of the mesoeconomy of Russia, the aggregate production of all its regions, can be attributed by the degree of industrialization $t\alpha$ to industrial type 2 and the degree of servicing $t\beta$ to service-oriented type 3. Such "mesoeconomic heterogeneity" may be related to the fact that many regions of Russia, which are related to service-oriented type 3, are subsidized, in connection with which they have a dominant service sector ($\langle t\beta \rangle \geq 2.1$ in table 2). Regions that can be attributed to the commodity-oriented type have an average degree of servicing $\langle t\beta \rangle \approx 0.9$. To study the structure of such heterogeneity, it is necessary to go to the

meso-level 2 - the level of the spheres of the national economy.

IV. CONCLUSION

The methodological approaches presented in this paper to the study of the meso-levels of the national economy made it possible to obtain theoretical results (hierarchical typology of the meso-levels of the national economy) and, based on the developed typology, to reveal statistical patterns in the intersectoral evolution of economic systems. The main task of the mesoeconomic analysis is to structure the transition from the micro level to the macro level of the country's economy and to obtain reliable information about the quality of the trajectory of the evolution of the development of the national economic system and the potential for implementing the fourth industrial revolution.

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