

# Model-Based Assessment of Efficiency of Structural Changes of the Russian Economy

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## ABSTRACT

The article consider the structure of the economy by sectors, studies the dynamics of indicators, characterizing the efficiency of economic development, and assesses, how they were affected by individual sectors and structural changes. To study the influence of the meso-level on the macro-level, models, that relate the parameters of production functions at different levels, are constructed, and calculations for the Russian Federation are carried out. An approach is proposed for determining the optimal structure of the economy under certain restrictions, and calculations for the Russian Federation are carried out. As a result, it was found that, compared with the pre-reform period, the influence of structural changes on the main economic indicators of Russia increased, and moreover structural changes had a positive effect in the 90s and negative in the 2000s, the structure of the economy has become significantly different from the optimal and their divergence is increasing. The efficiency of the Russian economy after growth at the turn of the century was rapidly declining in the 2000s, its growth resumed after the crisis of 2008-2009, but it is held by the negative influence of structural changes.

**Keywords:** labor productivity, efficiency, model, structure of the economy

## 1. INTRODUCTION

The modernization of traditional manufacturing industries is now in a large measure associated with the penetration of information technology and the digitalization of economic processes. The introduction of digital technologies in the Russian economy is increasingly affecting the competitiveness of Russian business, they contribute to the economic and technological development of territories. Introduced digital technologies can improve the efficiency of production management processes. They also create the basis for the formation of new approaches to analytical studies, prediction and management decision-making.

Prediction requires the creation of mathematical models, that would allow to analyze the development for the previous period in order to efficient management management decision-making. At the macro- and meso-level, it is necessary to pay the main attention to investment decisions, to identify areas, that will contribute to the most successful development. The predictions, built by mathematical models, will make it possible to make well-grounded strategic decisions.

The main indicators of the development of the macro- and meso-level relate production functions. They can be built by individual industries or regions, and when aggregated, they give the parameters of the production function of a higher level. The task of determining the interrelation between the parameters of production functions of two levels was posed quite a long time ago [1; 2]. It was

considered as a search for an optimal allocation of resources, primarily investments. In later studies, other approaches were proposed, as a rule, not related to the search for optimal solutions [3; 4; 5]. Usually, various mathematical problems, arising from aggregation, were studied [6, 7].

The aggregation problem caused a lot of discussions, associated with the possible interpretation of the obtained results [8; 8; 10; 11; 12; 13]. In recent years, new approaches have been proposed and new results have been obtained [14; 15; 16]. The importance of solving the problem of aggregation is associated with the need to assess the influence of individual sectors and structural changes on the studied macroobjects. This problem is associated with the construction of production functions, for the Russian Federation and its sectors (industries and regions), approaches were clarified and assessments of the main parameters were obtained [17, 18]

This article presents an approach on the basis of which a model is developed, that relates the parameters of the production functions of the macro- and meso-level and allows to assess the effect of structural changes [19; 20]. The purpose of the article is to study the dynamics of the efficiency of the economy of the Russian Federation and its sectors (industries and regions) on the basis of mathematical models, and to assess the influence of structural changes and major sectors on the efficiency of the economy of the Russian Federation. To solve this

problem, it is necessary to distinguish the main sectors, build comparable data series, which is difficult, given the constant change in methods, further analyze the charts of indicators and build the dynamics of indicators, that determine development efficiency. To assess the influence of structural changes, it is necessary to build production functions by sectors and by economy as a whole.

## 2. METHODOLOGY AND DATA

$$\Delta y(t) = \sum_i \frac{L_i(t-1)}{L(t-1)} \times (y_i(t) - y_i(t-1)) + \sum_i y_i(t) \times \left( \frac{L_i(t)}{L(t)} - \frac{L_i(t-1)}{L(t-1)} \right) \quad (1)$$

where:  $y(t)$  is labor productivity;  $\Delta y(t)$  is its increase over the year;  $L(t)$  is the number of employees;  $i$  is the sector;  $t$  is the year. In formula (1), the first summand is the influence of the increase in labor productivity in individual sectors, the second - is the influence of structural changes (changes in the share of sectors by employment). As a result of the calculations, it is determined, how the influence of sectors and structural changes on the dynamics of labor productivity at the macro-level during the considered period changed.

The next efficiency indicator is the fund elasticity, which shows by how many percent GDP (GVA or GRP sector) will grow with an increase in fixed assets by 1%. Instead of fixed assets, the article considered cumulative investments for five years, since fixed assets were underutilized in the 1990s, many enterprises worked with low load.

For the parameters of the production functions of the meso- and macro-levels, the following ratios were previously obtained, that relate their factor elasticities [20]:

$$\varepsilon_K = \sum_i \varepsilon_{Ki} \times \frac{Y_i(t)}{Y(t)} \quad (2)$$

$$\varepsilon_L = \sum_i \varepsilon_{Li} \times \frac{Y_i(t)}{Y(t)} \quad (3)$$

$$\varepsilon_K = \frac{(Y(t) - Y(t-1))/Y(t-1) - (L(t) - L(t-1))/L(t-1)}{(K(t) - K(t-1))/K(t-1) - (L(t) - L(t-1))/L(t-1)} \quad (4)$$

To assess the influence of structural changes, we used the previously obtained ratios, relating the Hicks-neutral technical progress with the parameters of the meso-level:

$$p = \sum_i p_i \times \frac{Y_i(t)}{Y(t)} + \varepsilon_0 \quad (5)$$

$$\varepsilon_0 = \sum_i (\varepsilon_K \times (\delta_{Ki} - \delta_K) + \varepsilon_L \times (\delta_{Li} - \delta_L)) \times \frac{Y_i(t)}{Y(t)} \quad (6)$$

where:  $\varepsilon_0$  - the influence of structural changes;  $p$  is the rate of neutral technical progress [Druzhinin].

To assess the efficiency, the dynamics of several indicators for 1990-2018 is built, the main indicator is labor productivity, which is calculated by gross domestic product (GDP) or gross value added (GVA) for industries or gross regional product (GRP) for regions. The increase in labor productivity of the Russian economy is the sum of the increase in labor productivity in individual sectors and structural changes:

where:  $Y$  - GDP (GVA, GRP);  $\varepsilon_K$  - fund elasticity;  $\varepsilon_L$  - labour elasticity;  $i$  - the sector index.

Formulas (2) and (3) make it possible to determine the influence of individual sectors on the change in factorial elasticity of the macro-level, which is determined by the share of the sector on production volume and the change in its factorial elasticity. To determine the dynamics of factorial elasticities of sectors, data smoothing were carried out and the dynamics of factorial elasticities of sectors was determined from the smoothed data, which made it possible to calculate their influence on the macro-level using formulas (2) and (3).

If assume, that sectors are described by linearly homogeneous production functions through logarithmic derivatives, then the fund elasticity with a zero rate of neutral technical progress is expressed through the ratio of the difference of the logarithmic derivatives:

$$\varepsilon_K = \frac{\delta_Y - \delta_L}{\delta_K - \delta_L}$$

where:  $\varepsilon_K$  - fund elasticity;

$$\delta_Y = \frac{\dot{Y}}{Y}, \delta_K = \frac{\dot{K}}{K}, \delta_L = \frac{\dot{L}}{L}, \text{ - logarithmic derivatives;}$$

$K(t)$  - the value of fixed assets (in the article, cumulative investments are for five years).

If go to the increases by the smoothed data, we get the following ratio for assessing the fund elasticity:

As a result of the calculations, the contribution of structural changes and individual sectors to the change in

the rate of neutral technical progress was determined. The obtained neutral technical progress  $p$  varies during the considered period, depending on the activity of structural changes and intrasectoral changes, associated with the modernization of production.

Cobb-Douglas production functions were calculated and, based on them, the optimal allocation of factors between

$$\frac{\varepsilon_{K_i} \times Y_i(t)}{K_i(t)} = \frac{\varepsilon_{K_j} \times Y_j(t)}{K_j(t)}$$

$$\frac{\varepsilon_{L_i} \times Y_i(t)}{L_i(t)} = \frac{\varepsilon_{L_j} \times Y_j(t)}{L_j(t)}, \quad i = 1, N, \quad j = 1, M$$
(8)

The optimal allocation is found by consecutive solution of several nonlinear equations using standard methods. If assume, that the functions have the same degree of homogeneity, then the system is transformed into one equation with respect to the ratio of indicators. Comparative calculations were carried out for different time periods.

To carry out calculations, information on the development of the economy of the Russian Federation, major industries (types of activity) and regions was collected for 1990-2017. The following indicators were considered: GDP, GVA, GRP, the number of employees and their structure, fixed assets and their structure, investments and their structure, as well as some other indicators. The data source is statistical reference books and the FSSS website ([www.gks.ru](http://www.gks.ru)). The data were recalculated into indices with respect to 2008, the values of indicators for 2008 were taken as 100%. The main problem was associated with a change in methods, in some cases there were correction factors on the FSSS website, in their absence they were assessed using available data.

Data analysis began with the construction of series of comparable data and their charts, then the interrelations of indicators were studied and the moments of changes in

sectors was determined [20, 21]. It was previously found, that the optimal structure is determined on the basis of a model, built for two levels, described by production functions, in which the simplest restrictions on the main parameters are used. To maximize production growth rates, the conditions for the optimal allocation of resources were obtained:

(7)

trends were searched. As a result, hypotheses about the form of production functions, the possible dynamics of the parameters were formed.

Five sectors (types of activity) were distinguished in the Russian economy — agriculture and forestry, industry, transport and communications, wholesale and retail trade and others, by which production functions were built, the dynamics of labor productivity and fund elasticity were determined. During the calculations, the influence of each of these industries and the structural changes between them on the dynamics of the efficiency of the Russian economy were assessed.

The structure of the Russian economy has changed appreciably over the past 25 years (table 1). The share of agriculture more than halved, the share of transport decreased appreciably, and shares of other industries increased. After a period of rapid growth in the 1990s, the share of trade began to decline. The share of industry fluctuated noticeably, after the devaluation of the ruble in 1998, it increased, after the crisis of 2008-2009 it began to decrease and subsequently grew slightly. Labor productivity increased in all sectors, slowly in agriculture and rapidly in industry.

**Table 1 Change in the structure of the Russian economy by type of activity, % (GVA, current prices)**

	1995	2000	2005	2010	2015	2017	2018
Agriculture and forestry	7.37	6.6	4.7	3.88	4.04	3.66	3.37
Industry	28.2	31.66	34.79	29.75	26.9	28	30.7
Trade	21.4	23.88	17.84	20.82	15.8	14.1	13.9
Transport and communications	12.34	9.06	9.42	9.2	9.2	9.6	9
Other	30.69	28.8	33.25	36.35	44.06	44.64	43.03

Information was collected on 79 regions of the Russian Federation for 1990-2017, four regions with the highest GRP were distinguished - Moscow, St. Petersburg, Moscow and Tyumen regions. All other regions were united in the "other" sector. The influence of each of these regions on the dynamics of the efficiency of the Russian economy was assessed. Till the mid-2000s, Moscow's

share grew rapidly, then growth stopped. The share of the Tyumen region depends on the level of hydrocarbon prices, in the other two regions, the growth in the share of GRP has stopped in recent years (table 2). The highest labor productivity was in the Tyumen region and Moscow, the lowest - in other regions. The labor productivity of other regions grew most slowly.

**Table 2 Change in the structure of the Russian economy by regions (GRP, current prices), %**

	1995	2000	2005	2010	2015	2016	2017
Moscow	10.26	20.14	22.93	22.22	20.73	20.56	20.98
St. Petersburg	3.33	3.27	3.69	4.51	5.19	5.29	5.16
Tyumen region	7.73	9.92	12.29	8.76	8.97	8.68	9.32
Moscow region	3.38	3.08	3.93	4.86	4.88	5.29	5.08
Other region	75.3	63.59	57.16	59.65	60.23	60.18	59.46

The growth of high-tech industries in the Russian Federation is unnoticeable. For example, the information and communication technology (ICT) sector is an efficient sector, labor productivity in the ICT sector is about one and a half times higher than in the economy as a whole. But since the second half of the 2000s, its growth rate has been lower than the average for the economy, its share in GDP is decreasing, it does not grow in investments, and the share in investments in 2018 is two times lower, than in the mid-2000s.

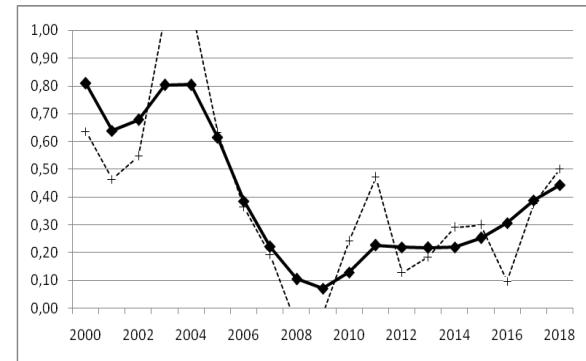
### 3. RESULTS AND DISCUSSION

An assessment of the efficiency of the allocation of investments and other resources during the reform period was made, whether it contributed to economic growth or not, and whether the share of the most efficient sectors increased or not. It is the share of the most efficient and rapidly developing sectors that is decisive for economic growth. To build charts and calculations, standard data processing packages EXCEL and STATISTICA are used. Based on the previously developed methodology, according to the results of a special analysis for each of the sectors and the Russian economy as a whole, the parameters of production functions were assessed. A preliminary assessment of the dynamics of the parameters was made on the basis of building charts and calculations, using simplified models and smoothed data.

When analyzing the influence of five industrial sectors and structural changes on the efficiency of the Russian economy, calculations were carried out by formulas (1) - (5). In the course of data analysis, the dynamics of labor productivity and its determining factors were studied. The influence of structural changes on it was noticeable till 2003, in some years it reached 39% of the total increase. Since 2004, it is insignificant again, not exceeding 4% of the increase, and it is negative in the 2010s - the share of industries with lower labor productivity is growing. The growth of labor productivity is largely determined by the modernization of production in sectors of the economy, primarily industry, which has provided approximately 40% of the total increase since 1999, the influence of other sectors is slightly less - 35%.

The fund elasticity of the Russian economy, determined by formula (4), turned out to be about unity in the late 1990s - early 2000s, which indicates the high efficiency of investments during this period. Then, the elasticity decreases and increases slightly after the crisis of 2008-2009, which is associated with the economic recovery in

the post-crisis period. In the 1990s, the main contribution to the elasticity value was made by industry, for some time, the contribution of agriculture was significant, but it quickly fell to almost zero. The contribution of other industries and trade was gradually growing, and since the 2000s, the main contribution to the growth belonged to other industries - about half, the contribution of trade grew up to a quarter, and the share of industry declined from one third to one sixth. In recent years, the efficiency of investments in industry has been growing (fig. 1). It should be noted, that till 1990, the change in the fund elasticity was almost completely determined by two industries - about 2/3 by industry and 1/3 by agriculture.



**Figure 1** Dynamics of fund elasticity of mining operations by cumulative investment for five years (dashed lines - dynamics of elasticity with one smoothing, solid line - with three smoothings)

The influence of structural changes on the growth of the Russian economy, determined by formula (6), turned out to be significant in some years. In the mid-1990s, the increase due to structural changes was approximately 1.2%, then it began to decrease and declined to 0.1% by the beginning of the 2000s, and in recent years, the influence of structural changes has been negative, and is approximately -0.6%. If we compare with the data for the USSR, then the influence of structural changes on the growth of the Soviet economy was small, only in 1962-1964. and in 1968-1970. the total influence of structural changes was almost 0.5% of the increase in total output. A comparative analysis of the real and optimal structure of the economy, determined using formulas (7) - (8), was carried out. For the Soviet economy, the optimal output in the 1970s and 1980s exceeded the actual output by about 40%. In the 2000s, the difference between the real and

optimal allocation of resources sharply increased, the optimal output exceeds the actual by 90-140%. If check the optimal allocation of investments, fixing the structure of employed by sectors, then it is slightly less than 20% for the Soviet economy. For the Russian economy, the real structure was fairly close to optimal till the 2000s, the difference is initially slightly more than 10%, but it grows, and in the 2000s it reaches 25%, investments are made in less efficient industries. When checking the optimal allocation of employees by industries (structure of funds was fixed) for the Soviet economy, a slight difference was noted (3-7%, and in some calculations, 1-2.5%), which shows, that the allocation of employees was close to optimal.

An analysis of the influence of regions on labor productivity in the Russian economy showed, that the industrial regions and Moscow had the greatest influence. The influence of the regions on the value of the fund elasticity turned out to be somewhat different, the influence of Moscow was unexpectedly high, about 40% in the 2000s. The influence of the Tyumen region is noticeable - about 9%, and in the mid-2000s - up to 18%. The influence of interregional structural changes on the one hand was noticeable, in some years, up to 38% of the increase in labor productivity was associated with a change in the regional structure, on the other hand, there was practically no influence on the whole over the entire period. The influence of interregional structural changes on the parameters of the production function and the growth rate of the Russian economy was assessed over the 2000s, and it turned out to be insignificant, usually it did not exceed 0.1%, only in 1999-2000 it exceeded 1%.

In the 70s and 80s, the optimal output exceeded the actual one by 46-47%, which is much less, than now, which means, that the allocation of resources is now further from optimal than before the reforms. The calculations showed a lack of optimality in the allocation of investments, rather, the policy before the reforms and in the 2000s was aimed at maintaining certain proportions of production by the regions and supporting the weak. The optimal structure was closest to the real in the time of fixing fixed assets and free flow of employees. The difference between the real and optimal structure before the reforms was 27-32%, which is less, than in calculations without restrictions, but still, the difference is quite large, since the availability of registration restrained the flow of employees and the approximation of the actual allocation of employees to the optimal one. This practice is observed now - the allocation of investments in the 2000s does not approximate the optimal, rather, there is a tendency to keep the existing structure of the economy.

#### **4. CONCLUSION**

An analysis of the influence of industries on the Russian economy indicators showed, that compared with the pre-reform period, the influence of structural changes increased, other sectors began to determine the dynamics of the efficiency of the Russian economy and the

difference between the real and optimal structure of the Russian economy became much larger. It should also be noted, that since the mid-2000s, resources began to be allocated in less efficient sectors of the economy, which did not allow to modernize the country's economy. The efficiency of the Russian economy declined rapidly in the 2000s after the growth at the turn of the century. After the economic crisis of 2008-2009 its growth resumed, but it is held by the negative influence of structural changes, and the share of less efficient industries is growing.

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