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APPLICATION OF THE INDEX METHOD OF FACTOR ANALYSIS TO STUDYING THE RATES OF TERRITORIAL ENERGY INTENSITY INCREASE (THE CASE OF MACRO-REGIONS OF THE RUSSIAN FEDERATION)

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Purpose: the article is devoted to the development of tools used for assessing and analyzing the comparative performance of the state energy efficiency policy. *Discussion*: we propose a method that allows taking into account the influence of technological and structural factors on the dynamics of energy intensity of a region, and not on the dynamics of its energy consumption. This peculiarity increases the relevance of calculation results to the target indicators of strategic planning and distinguishes this research from other studies based on the index method of decomposition. The energy intensity is considered for all energy resources, not only for electricity, which became possible due to the availability of qualitatively new data in the Rosstat database. *Results*: we have carried out the comparative analysis of energy policy performance of the Russian macro-regions on the basis of differentiated accounting for the influence of technological and structural factors on energy intensity growth rate of these territories. The calculations are based on the Rosstat data for the period of 2012-2017.

Keywords: index method of factor analysis, decomposition of an indicator increase, energy-economic development, energy intensity of economy, energy efficiency, economic growth, structural factor, inter-regional comparisons, regional economy.

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Introduction

Russia is pursuing an active state policy aimed at improving the efficiency of the use of all types of fuel and energy resources, including electricity. Wasteful energy consumption in production and in everyday life leads to a decrease in the competitiveness of goods and services, to a reduction in real incomes of the population [11]. Economic development of territories is so closely related to the nature and efficiency of energy consumption that in regional research, the concept 'energy-economic development' is increasingly used in the meaning of studying the dynamics of economic indicators in conjunction with energy consumption indicators [5, 8].

On 4 June 2008, decree of the President of the Russian Federation No. 889 «On some measures to improve the energy and environmental efficiency of the Russian economy» set the goal to reduce energy intensity of the economy by 2020 by 40% as compared to the level of 2007 year.

The Energy Strategy of Russia for the period up to 2030 (hereinafter – ES-2030) approved in 2009 stipulates that by 2030 the energy intensity of the Russian economy should make 44% of the level of 2005 year.

Today, the current version of the draft updated Energy Strategy of Russia for the period up to 2035 (hereinafter – ES-2035) is available on the website of the Ministry of Energy of the Russian Federation. This document indicates that over the period 2008-2018, the energy intensity of the Russian economy actually decreased by 9.3% in the prices of 2018 year.

If we assume that the decrease in energy intensity was planned and occurred evenly, then it is easy to show that over the period 2012-2017, energy intensity should have decreased by a value from 7% (according to Decree of the President of the Russian Federation No. 889 of 4 June 2008) to 12.66% (according to ES-2030) in constant prices of 2012 year, but in fact it decreased by 4.83% (according to ES-2035) [2].

To increase the effectiveness of the state energy efficiency policy, it is of great importance to improve monitoring of energy consumption based on the further development of tools and methods for assessing and analyzing the rationality of energy use in all spheres of the national economy [6, 7].

To achieve the target indicators for reducing energy intensity, it is important to know how these indicators change both within Russia as a whole and in the territorial context, since the regions are highly differentiated according to the conditions and levels of economic development [1].

According to the above-mentioned strategic planning documents, the reduction of energy intensity will be ensured through special measures of the state energy efficiency policy based on the development of new technologies (i.e. under the influence of the technological factor). However, energy intensity also depends on economic growth and on the structural factor, the effect of which is expressed in the uneven development of gradations in the GRP structure.

Comparative estimation of energy policy performance of the regions requires application of the tools allowing for differentiated consideration of the effect of various factors, such as the index method of decomposition of the increase in energy consumption [3, 9, 10, 12].

In the work [4], this method was applied in relation to the growth rate of electricity consumption in the regions of the Russian Federation for 2005-2013. The factors of economic growth, structural shifts and technological changes were considered. While working on [4], the authors did not have access to the data on total consumption of all fuel and energy resources, since these data were not covered by Rosstat in the annual reports. Therefore, the authors considered only electricity consumption. At the same time, the data available at that time made it possible to consider the GRP in the sectoral context and to take into account structural changes as the effect of the structural factor.

Currently, the Rosstat website provides the data on total consumption of all fuel and energy resources, including electricity, in the regional context, not in the sectoral one. Regions are grouped into macro-regions and Federal Districts. Therefore, in this paper, we consider the consumption of all energy resources by the macro-regions of the Russian Federation, and the gross products of the territories included in these macro-regions are used as the structural gradations of GRP. We propose a method of differentiated accounting of the influence of technological and structural factors on the rate of energy intensity increase in contrast to the rate of energy consumption increase. This approach seems to be more relevant for assessing the performance of energy efficiency policy in the regions.

Methodology

1. Agreed designations

E_i and E – volumes of total energy consumption (for all types of energy resources) of the i-th territory as part of a macro-region and the macro-region as a whole (total for all territories);

A_i and A – gross regional product of the i-th region as part of a macro-region and the macro-region as a whole;

X_i and X – GRP energy intensity, i.e. specific electricity consumption (per unit of gross product) in the economy of the i-th region and in the economy of the macro-region as a whole:

$$X_i = \frac{E_i}{A_i}; \; X = \frac{E}{A}. \quad (1)$$

S_i – share of sector of the i-th region in the macro-region GRP:

$$S_i = \frac{A_i}{A}. \quad (2)$$

We will use superscripts to designate a time period: 0 – base period (the beginning of the considered time interval), t – reporting period (the end of the considered time interval).

Then the growth rate of energy intensity of a territory will have the form:

$$T == \frac{X^t}{X^0}. \quad (3)$$

The correct calculation of indicator *T* requires expressing the energy intensity in both periods (0 and *t*) in constant prices.

1. Calculation formula of the index method of factor analysis of the

relative increase in energy consumption of a macro-region and interpretation of decomposition

As shown in [3], the growth rate of energy consumption in a macro-region can be decomposed into three parts:

$$\delta E = \frac{E^t - E^0}{E_0} = I_A + I_S + I_T; \tag{4}$$

$$I_A = \frac{\left(A^t - A^0\right) \cdot \sum S_i^0 I_i^0}{E_0}; \tag{5}$$

$$I_S = \frac{A^t \cdot (\sum S_i^t \cdot I_i^t - \sum S_i^0 \cdot I_i^t)}{E_0}; \tag{6}$$

$$I_T = \frac{A^t \cdot (\sum S_i^0 \cdot I_i^t - \sum S_i^0 \cdot I_i^0)}{E_0}. \tag{7}$$

In equations (4)-(7), I_A, I_S and I_T are contributions of three factors (economic growth, structural shifts and technological changes) to the dynamics of energy consumption in the macro-region at other conditions being equal.

In the considered decomposition of the growth rate δE, the actions of three indicated factors are taken into account and interpreted as follows. Economic growth is expressed in an increase in the GRP of territories (in constant prices of the base period); in the course of economic growth, energy intensity of a territory decreases at the condition that other indicators are equal.

Structural shifts mean that the regions included into a macro-region are developing unevenly, and their GRP as components of the macro-region's GRP change disproportionately. If, other conditions being equal, a region with a relatively high (or relatively low energy intensity) increases its share in the GRP of a macro-region, then the energy intensity of the macro-region accordingly increases (or decreases) regardless of the measures of state energy efficiency policy.

A decrease in energy intensity of any territory, other conditions being equal, is considered as a consequence of the technological factor associated with implementation of the measures of state energy efficiency policy. Reduction in energy intensity under the influence of the technological factor is most relevant for assessing the energy policy performance of the region.

2. Decomposition of the rate of energy consumption increase by contributions of structural and technological factors based on the existing energy consumption increase decomposition

Let us supplement the above-described methodology for the factor analysis of energy consumption dynamics of a territory with decomposing the rate of energy consumption increase by structural and technological factors.

We should point out that the contribution of economic growth to the increase in energy consumption coincides with the rate of changes in GRP. This is verified by formula (5) taking into account the meaning of the introduced designations:

$$I_A = \frac{\left(A^t - A^0\right) \cdot \sum S_i^0 I_i^0}{E_0} = \frac{\left(A^t - A^0\right) \cdot \frac{E_0}{A_0}}{E_0} = \frac{\left(A^t - A^0\right)}{A_0} = \delta A. \quad (8)$$

In the given equation, all relative values are expressed in fractions, not in%.

Let us decompose the increase in the energy intensity of the macro-region by contributions of structural and technological factors based on the already existing decomposition of this indicator:

$$X^t = \frac{E^t}{A^t} = \frac{E^0(1+\delta E)}{A^0(1+\delta A)} = \frac{E^0(1+I_A+I_S+I_T)}{A^0(1+\delta A)} = \frac{E^0(1+I_A+I_S+I_T)}{A^0(1+I_A)} = \quad (9)$$
$$= \frac{E^0}{A^0}\left(1+\frac{I_S}{(1+I_A)}+\frac{I_T}{(1+I_A)}\right) = X^0(1+I_{SA}+I_{TA}).$$

Thus, we have divided the contributions of structural and technological factors to the rate of increase in energy intensity. In both cases, economic growth is taken into account:

$I_{SA} = \frac{I_S}{1+I_A}$ – contribution of the structural factor to the rate of energy intensity increase; (10)

$I_{TA} = \frac{I_T}{1+I_A}$ – contribution of the technological factor to the rate of energy intensity increase. (11)

Calculation of the growth rates of macro-regions' energy intensity (not their energy consumption) and the subsequent differential accounting of the impact of technological and structural factors on the increase of this indicator make it possible to upgrade the validity of conclusions on comparative performance of energy policies implemented in macro-regions.

Results of calculations

The proposed methodology has been applied to assessing the performance of the energy efficiency policy of Russian macro-regions. The calculations are based on open official data available on the Rosstat website for the period from 2012 to 2017.

At the first stage, the dynamics of energy efficiency of macro-regions was investigated by calculating the growth rate of energy intensity (*T*) according to formula (3) for the period 2012-2017. The results are illustrated in Fig. 1, where the solid horizontal line *T=1* corresponds to the case when the level of energy intensity was stable over the period under consideration; at *T<1* it decreased, and at *T>1* it increased. The dotted line in Fig. 1 denotes the upper limit (*T=0.93*) of the range (*0.8734 <T<0.93*), which corresponds to the requirement described in the introduction on reducing energy intensity by 7% – 12.66% of the initial level for the period 2012-2017. As Fig. 1 shows, 7 out of 12 macro-regions fit into the specified range. Energy intensity in these regions decreased by more than 7% (*T<0.93*). In the South Siberian and Volga-Ural regions, it decreased by less than 7%, while in the Central, Northern and North-Western macro-regions, it even increased.

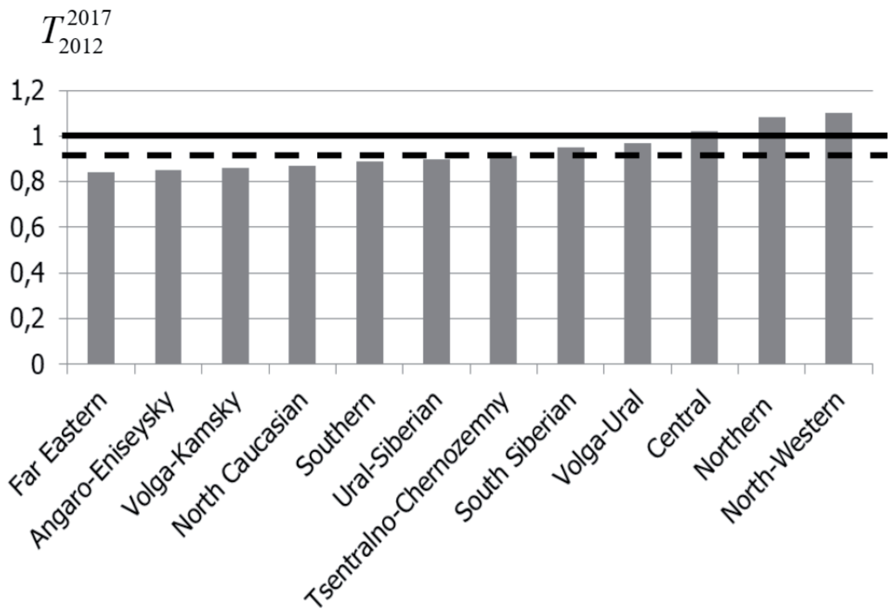

Fig. 1. Growth rates of energy intensity of macro-regions of the Russian Federation in 2012-2017

At the second stage of the study, it is advisable to carry out a differentiated account of the contributions of technological and structural factors to the energy intensity increase on the basis of the proposed methodology. The fact is that without eliminating the contribution of the structural factor to the increase in energy intensity, conclusions about the correspondence of this dynamics to the target settings will not be entirely adequate. This can be explained by the example of the Southern macro-region (the Southern Federal District). Data on this macro-region are presented in Fig. 2.

Fig. 2 shows a high degree of differentiation of the regions included in the Southern Federal District, in terms of energy intensity. Thus, this figure for the most energy-consuming Volgograd region is almost twice as high as for the Krasnodar Krai. If we now assume that, all other things being equal, the share of the Krasnodar Krai in the GRP structure is growing (at the constant level of energy intensity), then this will lead to a decrease in the energy intensity of the Southern Federal District without any special energy efficiency measures. This result does not provide any qualitative information about performance of the energy efficiency policy, in contrast to the technological factor's contribution.

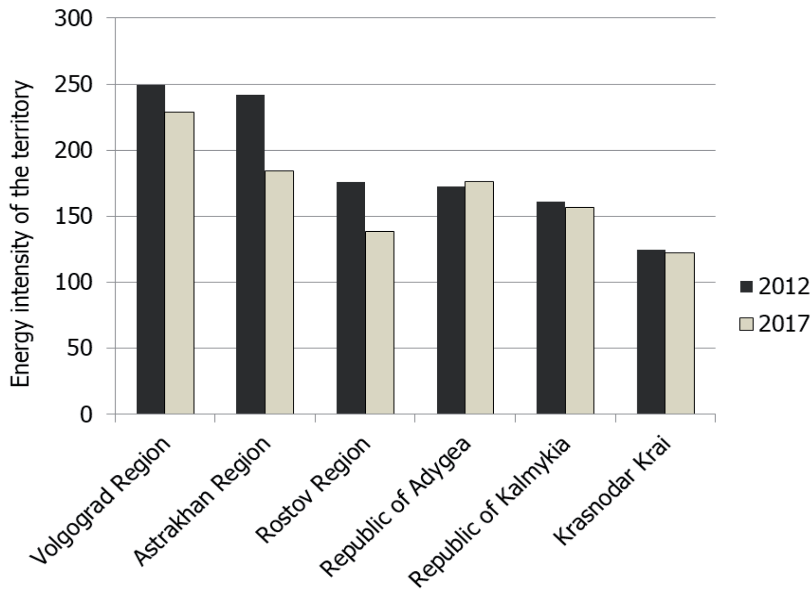

Fig. 2. Energy intensity of territories of the Southern macro-region in constant prices of 2012 (kg of fuel equivalent per 10 thousand rubles). Compiled on the basis of author's calculations according to the Rosstat data.

The results of energy intensity increase decomposition by technological and structural factors is presented in Table 1.

Table 1

Decomposition of energy intensity increase in Russian macro-regions by technological and structural factors

Macro-region of the Russian Federation	Rate of energy intensity increase $\delta X = (1-T)\cdot 100\%$	Contribution of structural factor I_{SA} (%)	Contribution of technological factor I_{TA} (%)
Far Eastern	-15,20	0,21	-15,41
Angaro-Eniseysky	-16,07	0,57	-16,64
Volga-Kamsky	-14,14	-0,16	-13,98
North Caucasian	-13,25	-0,47	-12,78
Southern	-11,33	-0,44	-10,89
Ural-Siberian	-10,07	-1,55	-8,52
Tsentralno-Chernozemny	-9,50	-0,44	-9,06
South Siberian	-4,58	-2,82	-1,76
Volga-Ural	-3,27	-0,41	-2,86
Central	1,78	1,80	-0,02
Northern	7,61	-2,72	10,33
North-Western	10,29	-0,21	10,50

Source: Compiled on the basis of author's calculations according to the Rosstat data.

As can be seen from Table 1, the share of technological factor significantly exceeds that of the structural factor in all macro-regions that reduced their energy intensity to the required level and below (from the Far Eastern to the Tsentralno-Chernozemny macro-regions). This indicates the sufficient performance of energy policy measures in these macro-regions. In the South Siberian, Volga-Ural and Central macro-regions, on the contrary, the contribution of the technological factor is insignificant (comparable to effect of the structural factor). Judging by the growth rate of their energy intensity, the energy policy performance in these territories is low. However, it should be noted that the reasons for the identified features of regional development require a more detailed study, taking into account additional information about circumstances of energy-intensive regional economies development.

Conclusion

Thus, the present article proposes the methodology that allows, on the basis of available official information, carrying out decomposition factor analysis of not only increase in energy consumption, but increment in the energy intensity of macro-regions as well. This means the possibility of differentiated accounting of impact of the technological factor (associated with energy policy performance) and the structural factor (i.e. shifts in the GRP structure that are not directly related to the energy efficiency policy) on energy intensity.

The methodology has been applied to assessing the performance of energy efficiency policy of macro-regions of the Russian Federation for the period from 2012 to 2017. The calculations are based on open official data available on the Rosstat website. Energy intensity has been considered taking into account the consumption of all types of fuel and energy resources, including electricity.

At the first stage of the study, the dynamics of energy efficiency of macro-regions has been investigated by calculating the growth rate of energy intensity (T) over the period 2012-2017. It has been revealed that 7 out of 12 macro-regions demonstrate compliance of energy intensity change rates with their target values established by strategic planning documents of Russian economy development. In the South Siberian and Volga-Ural macro-regions, the energy intensity had been decreasing at a too low rate, while in the Central, Northern and North-western macro-regions, it even increased.

At the second stage, according to the methodology proposed in the article, a differentiated accounting of the contributions of technological and structural factors to the increase in energy intensity has been carried out. It has been revealed that in all macro-regions that lowered their energy intensity to the required level and below, the share of the technological factor significantly exceeds the share of the structural factor. This indicates the sufficient performance of energy policy measures in these macro-regions. In the macro-regions demonstrating low rates of energy intensity decrease or even an increase, on the contrary, the contribution of the technological factor is insignificant (comparable to the structural one). According to the growth rate of their energy intensity, the energy policy performance in these territories is low. However, it should be noted that the reasons for the identified features of regional development require a more detailed analysis.

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ПРИМЕНЕНИЕ ИНДЕКСНОГО МЕТОДА ФАКТОРНОГО АНАЛИЗА К ИССЛЕДОВАНИЮ ТЕМПОВ ПРИРОСТА ЭНЕРГОЕМКОСТИ ТЕРРИТОРИЙ (НА ПРИМЕРЕ МАКРОРЕГИОНОВ РФ)

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Цель: статья посвящена развитию инструментов, используемых для оценки и анализа сравнительной результативности государственной политики энергоэффективности территорий. *Обсуждение*: предложена методика, позволяющая дифференцированно учесть влияние технологического и структурного факторов на динамику энергоемкости региона, а не на динамику его энергопотребления. Эта особенность повышает релевантность результатов расчетов целевым показателям стратегического планирования и отличает данную работу от других исследований, основанных на индексном методе декомпозиции. Энергоемкость рассмотрена по всем энергоресурсам, а не только по электроэнергии, что стало возможным благодаря появлению качественно новых данных Росстата. *Результаты*: выполнен компаративный анализ результативности политики энергоэффективности российских макрорегионов на основе дифференцированного учета влияния технологического и структурного факторов на темпы прироста энергоемкости этих территорий. Расчеты выполнены на основе данных Росстата за период с 2012 по 2017 год.

Ключевые слова: индексный метод факторного анализа, декомпозиция прироста показателя, энергоэкономическое развитие, энергоемкость экономики, энергоэффективность, экономический рост, технологический фактор, структурный фактор, межрегиональные сравнения, региональная экономика.

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