ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

International Journal of Engineering Technologies and Management Research
A Knowledge Repository
IJETMR

STRUCTURAL AND DYNAMIC APPROACH TO ANALYZING THE ENERGY INTENSITY OF RUSSIAN REGIONS' GRP OVER THE PERIOD 2005-2014

Bogachkova L. Yu.[*1], Khurshudyan Sh. G. [2]
[*1] Regional Economics and Management School, Volgograd State University, Russia

Abstract:
Today, the Russian system of accounting energy consumption indicators is being actively developed, the special attention being paid to collecting verified statistical data and methodological grounding of energy efficiency monitoring in the regions. The present paper outlines the approach to estimating structural factor's effect on energy intensity of Russian regions. The approach consists in grouping Russian regions by types of their energy-economic development; studying dynamic characteristics of each group; estimating the intensity of GRP structural shifts; and analyzing statistical interdependence of structural shifts' intensity and energy intensity dynamics across the regions. The paper deals with the first stage of implementation of Energy Strategy of Russia for the Period up to 2030 (over 2005-2014 years). The dynamics of energy efficiency has been investigated using the case of electricity consumption. The results obtained in the present research show the slight impact of structural factor on energy intensity dynamics in the Russian regions, which complies with the earlier obtained results. Thus, over the period 2005-2014 the energy intensity dynamics in the Russian regions could be substantially affected by economic growth, technology modifications and other factors requiring detailed studies.

Keywords: Energy Efficiency; Electric Intensity; Regional Economy; Energy Efficiency Index; Regional Typology; Energy-Economic Development; Structural Changes.

Cite This Article: Bogachkova L. Yu, and Khurshudyan Sh. G. (2018). "STRUCTURAL AND DYNAMIC APPROACH TO ANALYZING THE ENERGY INTENSITY OF RUSSIAN REGIONS' GRP OVER THE PERIOD 2005-2014." *International Journal of Engineering Technologies and Management Research,* 5(12), 43-59. DOI: 10.5281/zenodo.2527617.

1. Introduction

Overview of up-to-date trends in both global and national economies shows that economic development of territories is closely connected with energy use efficiency: the faster the rates of economy's energy intensity reduction, the higher the rates of economic growth (International Energy Agency, 2017; Makarov, Grigoryev & Mitrova, 2016; Ivanov & Matveev, 2017). Comprehensive reviews of modern literature on macroeconomic effects of energy efficiency growth are presented in (Naess-Schmidt, Hansen & von Below, 2015; Saldanha, Gouvea da Costa & de Lima, 2018).

Energy intensity is an indicator of energy consumption efficiency which is determined as the ratio of gross product to overall costs of energy expressed in physical units. A low level of energy

ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

efficiency (excessive energy intensity) of certain production processes incurs the increase in average production costs, and, as a result, downward competitiveness of final output. Uneconomical consumption of energy resources in non-production sphere has a negative impact on population's living standards, as it leads to rising expenses on domestic energy use and consequential deterioration of living conditions. Accordingly, energy efficiency increase is an essential condition for ensuring economy's competitiveness and a priority area of state economic policies of various countries and their alliances (Inshakov, Bogachkova & Popkova, 2019).

The key role of energy efficiency increase in competitive and stable economic growth has got reflection in the special term 'energy-economic development'. In 2014, Directorate General for Economy and Finance as part of European Commission published special report "Energy-Economic Developments in Europe" (EU, 2014). The similar term is used in a number of Russian researches (Bury, Kalinina, Kukresh, 2008; Golovanova & Ivanchenko 2010). The notion of economic development is defined as expanded reproduction and gradual positive qualitative and structural changes in the economy, productive forces, education, science, culture, living standards, and human capital (Economic Glossary of Terms and Concepts). Taking this definition into account, term 'energy-economic development' should be understood as ensuring expanded reproduction, gradual positive qualitative and structural changes in the economy and territory's competitiveness through increased energy use efficiency as a key production factor (Khurshudyan, 2017: 18).

The core factors affecting the economy's energy intensity include economic growth, structural changes and technology updates with the latter one being the most relevant from the viewpoint of policy's energy efficiency (Ang & Zhang, 2000; Ang & Zhou, 2010; Bashmakov & Myshak, 2012).

The world practice shows that the monitoring of energy efficiency policy performance requires the use of various energy efficiency accounting systems (EEAS) having common features as well as national peculiarities. Most of them are based on index decomposition analysis (IDA) allowing the differentiated accounting of various factors' contribution in energy consumption growth (Ang & Zhang, 2000; Tian Goh & Ang, 2018; Ang, 2004). Besides, the technique of energy efficiency estimation known as Data Envelopment Analysis (DEA) developed in (Charnes, Cooper & Rhodes, 1978) is becoming more common. The DEA consists in studying complex objects (territories, enterprises, production process) with numerous inputs (costs) and outputs (product release) and analyzing their functioning as compared to other analogous objects. The prospects of the DEA application in modern research on regions' energy efficiency are shown in (Fanyi Meng, Bin Su & Yang Bai, 2018; Bangzhu Zhu, Bin Su & Yingzhu Li, 2018).

Continuous structural changes peculiar of any economy is one of the key factors affecting the dynamics of energy efficiency. In a wide sense, structural changes in the economy are shifts in sectoral structure, property structure, reproduction structure as well as in the structures of production funds, labour resources, consumption, saving, investments, foreign trade, etc. And in a narrow sense, structural changes effect only gross product. Analysis of structural changes impact on energy intensity of different countries plays one of the key roles in energy efficiency monitoring and is consistently considered to be a relevant technique in research and practice investigations (Jenne & Cattell, 1983; Farla, Cuelenaere & Blok, 1998; Acharya & Dash, 2006; Haas & Kempa,

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

2018). It should be noted that the choice of research method and accuracy of structural changes' effect estimation depend largely on the quality of energy efficiency accounting systems.

Today, the Russian system of energy efficiency accounting is at the stage of development. Since 2014, State reports on energy saving and energy efficiency increase in the Russian Federation have been published on the Internet by the Ministry of Energy of the Russian Federation (2015, 2016, 2017, 2018). At the regional level, specific energy consumption is estimated in various production processes with account of product differentiation and production stages; a wide range of factors effecting energy consumption patterns is taken into consideration. Besides, the regional subsystem of energy efficiency monitoring is characterized with a low level of sophistication as far as collection of verified statistical data is concerned, and is not secured by unified methodological materials. The factor analysis of GRP energy intensity is not carried out at the regional level while preparing State reports.

Thus, working out the tools for decision-making support in the sphere of estimating the performance of energy efficiency policy of Russian regions is an important economic task. From the scientific viewpoint, estimating the impact of different factors on energy efficiency in the Russian Federation constitutes a relevant task. For example, the structural factor's effect on energy intensity of the Russian economy is a debating point. On the one hand, the updated Energy Strategy of Russia for the Period up to 2035 [Draft] prepared by the Ministry of Energy of the Russian Federation (2017b) points out that the key contribution to energy intensity reduction of the 2000s was made by structural changes and economic growth, while the impact of technological factor was slight. On the other hand, the State report on energy saving and energy efficiency in the Russian Federation for 2017 which was prepared for the first time by the Ministry of Economic Development, testifies to insignificance of both energy intensity reduction and structural changes' impact (Ministry of Energy of the Russian Federation, 2018).

The previous research by Bogachkova & Khurshudyan (2015; 2016; 2017) based on decomposition method let estimate the impact of structural shifts, economic growth and technological modifications on electricity consumption in Russian regions in 2005-2014. In particular, calculations show that the average index of GRP electricity intensity in Russian regions as a whole went down by 18% in 2005-2014 (2% higher than target value set for 2015 in ES-2030); furthermore, electricity consumption increased by 11%, including: +37% – due to economic growth; –19% – due to technological factor; –7% – due to GRP structure change. Therefore, the structural factor's effect on the dynamics of energy consumption played a subordinate role. However, it should be noted that the above estimates are very rough, since, due to the limited statistical data available, the method of electricity consumption decomposition was used in a very simplified form. The technological factor's effect was estimated according to the dynamics of average by-sector indices of electrical intensity without using disaggregated exogenous data on the energy intensity of individual production processes. This technique allowed obtaining only initial approximations to the estimates of three main factors' contribution to the dynamics of electricity consumption.

The present paper outlines and tests the authors' approach to studying the effect of structural factor on energy intensity of Russian regions consisting in their grouping by the type of energy-economic development depending on GRP structure; investigating the dynamic properties of each group;

ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

estimating the intensity of GRP structural changes; and analyzing statistical interdependence of changes' intensity and regions' energy intensity.

The choice of period from 2005 to 2014 – the first stage of the Energy Strategy of Russia for the Period up to 2030 – is conditioned by several prerequisites: firstly, it is feasible to compare the achieved levels of energy efficiency with their target values by 2015; secondly, the given period is characterized as a new stage of energy-economic development of Russia against the background of aggravated foreign policy situation, economic sanctions imposed by Western countries on Russia and the onset of high volatility in world oil prices.

The dynamics of energy efficiency has been investigated using the case of electricity consumption, since the official statistics necessary for the calculations are available on the website of the Federal State Statistics Service (Rosstat) only for this energy resource.

2. Methods

The research is based on the authors' methodology for grouping entities of the Russian Federation by the type of their energy-economic development and for estimating groups' time-stability; linear coefficient of relative structural changes in GRP; energy intensity index (exemplified with electricity consumption); the method of identifying the statistical relationship between the indicators of structural changes in the GRP and the electrical capacity of regions.

2.1. The Method of Russian Regions Classification by the type of their Energy-Economic Development is based on

The principles worked out by Bogachkova & Khurshudyan (2014) and described in detail by Khurshudyan (2016). It consists in singling out the homogeneous groups of Russian regions with a similar structure of GRP. The elements of each group differ from the elements of other groups by the predominance in the structure of their GRP (as compared to the average structure of GRP across the regions) of one or another GRP sector.

At the first stage, the collection of data is carried out, including the formation of integrated sectors in GRP structure; sorting out the regions having extremely large shares of certain economic sectors in their GRP structure; determining the average structure of GRP by the adjusted set of regions.

The following integrated sectors of GRP structure were allocated:

- Agrarian-bioresource (agriculture, hunting and forestry; fishing, fish-farming);
- Raw-material (extraction of mineral resources);
- Industrial (manufacturing industries; production and distribution of electricity, gas and water; construction activities);
- Trade-financial (wholesale and retail trade; maintenance of motor vehicles, household goods and personal appliances; financial activities; real estate operations, leasing, provision of municipal, social and personal services; hotels and restaurants; transportation and communication);
- Budget-dependent (public administration and military security; social insurance; education; health and social services).

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

At the second stage, it was necessary to reveal a homogeneous group of diversified regions with the GRP structure close to the average one across the total set of Russian entities. Diversified regions are entities of the Russian Federation, where the shares of integrated economic sectors in GRP structure are close to the corresponding average values across the total set of regions. It should be noted that the shares of GRP are unevenly distributed among integrated sectors. The identified diversified regions were excluded from the analyzed set of Russian entities.

At the third stage, the identification of 5 intersectional groups of regions with one-type production specialization took place. The regions were grouped by 5-step k-means clustering – by two different indicators at each i-th step. The first indicator is the share of the i-th integrated sector in GRP (%), and the second indicator is the total share of all the rest integrated sectors with $1\leq i\leq 5$. Thus, at each i-th step of clustering a group of regions with the i-th profile sector was singled out. Then, without excluding the resulting group from the set under study, we obtained crossing groups of regions that differ in their production specialization in each of the 5 integrated GRP sectors.

Note that one region can specialize in several production areas. Data processing can be performed in any software package of statistical data processing, such as STATISTICA 7.0. or IBM SPSS Statistics 22.

At the fourth stage, the final group of Russian regions diversified by GRP structure was allocated. This stage consists in determining the degree of homogeneity of formed groups and including those regions which were intentionally excluded from analysis due to strongly pronounced production specialization (abnormal structure).

2.2. The Method of Estimating the Time-Stability of Developed Classification of Russian Regions over the Period under Study.

The built grouping of regions is subject to changes over time due to irregularity of structural shifts: some regions may fall out of one group and enter another one. At the same time, all groups have sustainable subsets consisting of regions which belong to one and the same group over the whole period. Let us refer to such subsets as ‘cores’ of the groups. The stability of a group can be estimated by two criteria: number of regions constituting the core (core weight) at the beginning of the period and the changes in this number over the whole period (the number of withdrawn and the number of included regions). Both criteria should be considered in percentage form with regard to initial composition of a group. The heavier the core weight and the less the scope of its change, the higher the group’s stability Table 2 shows these indicators, rankings of groups based on them, as well as the resulting ranking of stability.

2.3. The Linear Coefficient of Relative Structural Changes in GRP Is used as an Indicator of Their Intensity.

It is calculated according to the formula (Sivelkin & Kuznetsova, 2002):

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

$$L_0^t = \frac{\sum_{i=1}^{n} \left| \frac{d_i^t}{d_i^0} - 1 \right|}{n} \quad (1)$$

Where and – values of i-th gradation of the GRP structure at the beginning (0) and at the end (t) of the period; n – general number of gradations in the GRP structure.

2.4. Index Of Energy Intensity of the Regional Economy (The Case of Electricity Consumption) is calculated according To the Formula:

$$Y = \frac{X^t}{X^0} = \frac{E^t \cdot A^0}{A^t \cdot E^0} \ , \quad (2)$$

Where – electrical intensity of GRP; – volume of electricity consumption; – gross regional product Index 0 is attributed to variable values at the beginning of the period, and index t – to variable values at the end of the period. It should be noted that gross regional product is taken into account in constant prices at the beginning of the period which allows excluding the impact of inflation and considering Y as the index of electrical intensity of GRP physical volume. It characterizes energy efficiency of the region in terms of electricity consumption. If Y<1, then electrical intensity of economy decreases, and if Y>1 – increases. Correspondingly, in the first case energy efficiency grows, and in the second case – reduces.

2.5. The Method of Identifying the Statistical Connection Between the Indicators of Structural Changes in

The GRP and the indicators of their energy efficiency (indices of electrical intensity of Russian entities) consist in calculation and standard statistical interpretation of the Pearson's correlation coefficient.

3. Results and Discussions

Appendix A presents the Russian regions grouped by the type of energy-economic development using the method described in 2.1 on the basis of data for 2005 and 2014 years. As can be seen from the Table, composition of each group had changed significantly over the given period. In 2005, each group reveals regions which fell out of those groups by 2014; and vice versa, some regions appeared in groups only by 2014. Besides, subsets of regions known as cores of the groups can be singled out in every group. The compositions of cores are presented in
APPENDIX B.

Changes in the number of one-type regions within each group are shown in Table 1. At the beginning of the period (2005), the industrial group was the largest and included 26 regions. Other groups were represented with 24 diversified regions; 16 agrarian-bioresource regions; 16 trade-financial regions; 15 raw-material regions; and 13 budget-dependent regions. By the end of the period under study (2014), only the number of diversified regions increased (from 24 to 26) which

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

made the corresponding group leading one. At the same time, the number of regions in all the other groups decreased. Since the GRP structure of diversified regions is close to the average one across the whole set of Russian regions, it is possible to observe a sort of convergence of the GRP structure of Russian regions over the period 2005-2014.

Table 1: The quantitative composition of groups of Russian regions with one-type energy-economic development (homogeneous in the GRP structure)

Types of regions	**Total number of regions**		**Fell into**	**Fell out**	**Core**
	2005	**2014**			
	Number				
Agrarian-bioresource	16	11	+3	– 8	8
Raw-material	15	16	+4	– 3	12
Industrial	26	18	+2	– 10	16
Trade-financial	16	15	+4	– 5	11
Budget-dependent	13	11	+1	– 3	10
Diversified	24	26	+9	– 7	17

Source: based on authors' estimations.

Numbers in the second and third columns do not coincide with the total number of regions under study since some regions are characterized by several types of development.

The groups of one-type regions identified in 2005 showed various levels of time-stability. The heavier the core weight and the less the scope of its change, the higher the group's stability. Values of these indicators and group rankings for each of them are shown in Table 2. It contains the resulting ranking of stability and its level.

Table 2: The level of groups' stability for two indicators: the core weight in the quantitative composition of the group at the beginning of the period and the scope of changes in the composition of the group over the period (fell out of the group plus fell into the group)

	Core		**Scope**		**Ranking (level) of stability**
	in % of number in 2005	**Rank**	**in % of number in 2005**	**Rank**	
Agrarian-bioresource	50	**5**	69	**6**	**11 (III)**
Raw-material	80	**1**	47	**3**	**4 (I)**
Industrial	69	**4**	46	**2**	**6 (II)**
Trade-financial	69	**4**	56	**4**	**8 (II)**
Budget-dependent	77	**2**	35	**1**	**3 (I)**
Diversified	71	**3**	67	**5**	**8 (II)**

Source: based on authors' estimations.

The resulting group ranking of stability can be commented using the example of diversified regions. The core weight of these regions reaches 71% with regard to initial quantitative composition. The rank for this indicator is equal to 3 (the group ranks 3rd among other groups). The scope of group's composition change makes 67% of the initial number. The rank for scope

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

index is equal to 5 (the 5th among other groups). The resulting ranking is defined as a sum of ranks: 3+5=8. This index refers to the second, average level of stability.

Table 2 shows that the groups of raw-material and budget-dependent regions were the most time-stable. They are characterized by the high – the first (I) level of stability. The average – the second (II) level of stability was demonstrated by the groups of industrial, trade-financial and diversified regions. And the low – the third (III) level of stability was attributed to agrarian-bioresource regions.

The general trend of structural changes in Russian entities is presented in Figure 1. It shows that on the average the weights of key sectors of production sphere reduced in industrial (from 31.61% to 29.1%) and agrarian-bioresource (from 11% to 8.9%) regions. The share of trade- financial sector decreased slightly as well (from 35.55% to 35.1%). At the same time, the share of budget-dependent sector increased largely (from 14.2% to 19.0%), and the raw-material sector showed slight increase (from 7.64% to 7.9%).

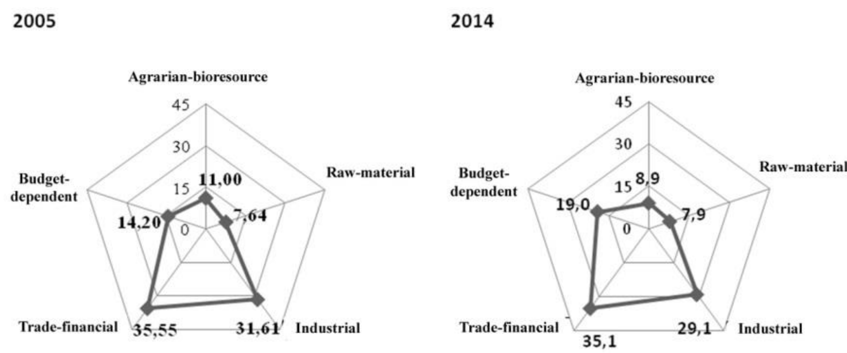

Figure 1: Average GRP structure across the total set of Russian entities in 2005 and 2014.

Thus, the common trend of structural changes in regional economies consisted in redistribution of GRP shares from production sectors (industrial and agrarian-bioresource) to non-production sectors (budget-dependent sector). The average intensity of structural changes in the Russian regions estimated according to the formula (1) made up .

The dynamics of GRP structure in the regions of a certain type (core average) can be determined using the data from Table 3. In this Table coefficient shows how many times the intensity of changes for regions of a certain type on average over the core is higher than the intensity of shifts on average in all regions of the Russian Federation.

The agrarian-bioresource regions are characterized by increment in the share of budget-dependent sector only (+3.37% points). Contribution of the industrial sector increased slightly (+ 0.41% points). Gradations of GRP structure corresponding to other sectors decreased. The intensity of structural changes is 1, 57 times higher above the average level across the total set of Russian regions. As compared to regions of other types, agrarian-bioresource entities of Russia are characterized by reduced share of profiling agrarian-bioresource sector (–1.11% points) and integrated share of industrial sector in the GRP structure. At the same time, in the regions of other types (core average), the contributions of industrial sector reduced.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

Table 3: Average shares of integrated economic sectors over the cores of one-type regions in the GRP structure for 2005 and 2014 years (in %); the intensity of structural changes as compared to the average Russian level $l = L^{2014}_{2005(core)} / L^{2014}_{2005(RF)}$ (, in times)

Economic sectors / Types of regions	Agrarian-bioresource		Raw-material		Industrial		Trade-financial		Budget-dependent		*l*
	2005	2014	2005	2014	2005	2014	2005	2014	2005	2014	
Agrarian-bioresource	19,96	18,85	2,96	2,80	25,76	26,17	32,24	29,72	19,08	22,45	1,57
Raw-material	6,38	4,48	29,03	30,56	26,13	23,36	28,43	26,77	10,03	14,84	1,16
Industrial	9,12	7,37	5,30	3,72	43,24	41,64	30,95	33,70	11,39	13,57	1,11
Trade-financial	8,94	6,01	2,52	2,15	27,88	26,91	47,62	48,21	13,05	16,71	1,44
Budget-dependent	14,83	11,24	5,90	3,95	22,22	21,36	32,06	30,53	24,99	32,92	1,81
Diversified	12,12	9,99	3,20	2,25	32,25	31,24	38,88	37,02	13,55	19,49	1,21

Source: based on authors' estimations.

Here, the inequality l>1 is not a controversial result, since not all regions of the Russian Federation were included in the core.

The raw-material regions demonstrated increments in the shares of budget-dependent sector (+4.81% points) and profiling raw-material sector (+1, 53% points). All the rest gradations of GRP structure reduced in these regions. The intensity of structural changes is 1.16 times higher above the average level across the total set of Russian regions. Increased contribution of raw-material sector is a peculiar feature of corresponding regions: for regions of other types the share of this sector in the GRP structure reduced (core average). Besides, on average the core of raw-material regions is characterized by slight reduction in the industrial sector's contribution (–2.77% points).

The industrial regions are characterized by essential increment in the shares of trade-financial and budget-dependent sectors (+2.75% points and +2.18% points, correspondingly); other core-average gradations of GRP structure reduced, including the share of profiling industrial sector (–1.6% points). The intensity of structural changes is close the average Russian level for this indicator (just 1, 11 times higher). The peculiar features of GRP structure in industrial regions (core average) are the largest increment in the share of trade-financial sector (+2,75% points) and reduction in the share of profiling industrial sector.

The trade-financial regions reveal the increment in the shares of budget-dependent sector (+3.66% points) and profiling trade-financial sector (+0.59% points). Other gradations of the structure reduced. The intensity of structural changes is 1.44 times higher above the average level across the Russian regions.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

The budget-dependent regions showed the maximum increase in the share of corresponding budget-dependent sector (+7.93% points). Other sectors' shares reduced with that of agrarian-bioresource one being the largest among all the other cores. The budget-dependent regions experienced the most intense structural changes exceeding the average Russian level in 1, 81 times.

The diversified regions experienced the major increase in the share of budget-dependent sector and reduction in all other sectors' shares in the core average structure of the GRP. The intensity of structural changes for the core of diversified group is 1,21 higher above the average Russian level.

Thus, the general trend of increasing the share of the budget-dependent sector in the GRP structure was manifested not only on average across the total set of Russian entities, but also among regions with certain sustainable types of energy-economic development. Peculiarities of structural changes were revealed only in the regions with sustainable industrial and trade-financial types of development (their share of trade-financial sector increased), as well as in the raw-material regions (the share of raw-material sector increased). Gradations of other integrated GRP sectors decreased on average across the cores of all groups.

Table 4: Paired coefficients of correlation between electrical intensity indices and indicators of structural changes' intensity, as well as the average values of these variables for the cores of one-type regions (2005-2014)

Types of regions	*Y* (average)	*L* (average)	Coefficients of correlation r_{YL}
Agrarian-bioresource	0,68	0,28	-0,69
Industrial	0,80	0,20	-0,34
Budget-dependent	0,80	0,32	-0,35
Diversified	0,81	0,23	-0,20
Raw-material	0,89	0,29	0,12
Trade-financial	1,12	0,24	0,23

Source: based on authors' estimations.

Studying the issue of structural factor's impact on electricity consumption dynamics required the calculation of indices of GRP's volume electrical intensity (Y) according to the formula (2). Average values of these indices and indicators of structural changes' intensity for the cores of one-type regions are presented in Table 4.

The agrarian-bioresource regions (Y=0,68) demonstrate the largest reduction in economy's electrical intensity (by 32%). This phenomenon is accompanied by relatively high intensity of structural changes (L=0, 28). However, the direction of these changes does not explain the dynamics of electrical intensity, since the redistribution of shares in the GRP structure proceeds within the non-production sphere rather than from electrically intense production sphere to non-production one (see Table 3). In fact, changes in the shares of agrarian-bioresource, raw-material and industrial sectors made about 1% and less than 1%. The trade-financial sector (–2.52%) and budget-dependent sector (+3.37%) made the largest contribution to the intensity of structural changes.

The budget-dependent, industrial and diversified regions rank the 2nd in electrical intensity reduction and have roughly the same index of 19-20% (see Table 4). Let us compare the directions

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

of changes' intensity in these regions (see Table 3). The industrial regions showed large increase in the shares of trade-financial and budget-dependent sectors due to the reduced contributions of agrarian-bioresource, raw-material and industrial sectors, while budget-dependent and diversified regions had the increased share of the budget-dependent sector only (to the most extent as compared to the regions of other types). It can be argued that these regions have similar directions of structural changes but absolutely different levels of these changes' intensity in the GRP structure. The budget-dependent Russian regions have the maximum level of intensity; the industrial regions – the minimal level; and the diversified regions – the average level. Moreover, these regions have roughly the same level of reduction in electrical intensity. t follows then that the structural factor (shifts in the GRP structure) cannot be used to explain differences in the dynamics of electrical intensity in these regions.

A similar statement holds true as far as the cores of raw-material and trade-financial regions are concerned. The results lead to the conclusion that the structural factor has a weak effect on the regional electrical intensity. This is also confirmed by the estimate of closeness between the electrical intensity index Y and the index of structural changes' intensity L. The paired coefficient of correlation between these indicators for the cores of groups of one-type regions is presented in Table 4. As it follows from its values, the statistical connection between the shifts in the GRP structure and the reduction in electrical intensity can be traced only in agrarian-bioresource regions.

Thus, the structural factor did not play the key role in increasing energy efficiency of Russian regions over the period 2005-2014. The closest connection of this factor with electrical intensity was demonstrated by the agrarian-bioresource regions. This conclusion complies with the results obtained earlier by the index decomposition analysis (Bogachkova & Khurshudyan, 2017). However, this method was used in a rather simplified form due to the limitedness of available statistical data.

It should be noted that the very interpretation of structural changes has a simplified form. Firstly, they are referred to only as changes in the sectoral structure of the GRP, while the term 'structural changes', or 'structural shifts' has broader meaning. Secondly, the changes in the GRP structure are considered as an objective phenomenon (from the viewpoint of energy efficiency policy), but at the same time they can result from the structural and/or industrial policy of the State.

The improvement of the Russian system for energy consumption accounting will lead to the further development of tools for analyzing the energy efficiency of Russian regions, which will make it possible to obtain more accurate estimates of structural and other factors' effect on the energy intensity of the economy in the process of energy-economic development.

4. Conclusions and Recommendations

The structural and dynamic analysis of the regional economy, carried out with account of the types of regions' energy-economic development, showed that the connection between the direction and intensity of structural changes in the economy, on the one hand, and the dynamics of the GRP electrical intensity, on the other hand, is very weak for regions with different types of energy-economic development with the exception of agrarian-bioresource regions. Consequently, the

ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

dynamics of electrical intensity in the Russian regions in 2005-2014 could be essentially affected by economic growth, technological modifications and other factors that require further detailed consideration.

The obtained results can be taken into account when analyzing the performance of the state policy of energy efficiency and special measures aimed at energy saving in the regions.

Acknowledgements

The research was funded by the Russian Fund of Fundamental Research and Administration of the Volgograd region, project "Development of tools for decision-making on estimating the effectiveness of energy saving policy and increasing energy efficiency of the region" No. 17-12-34041-OGN.

5. Appendices

Appendix A: Classification of Russian regions by the type of energy-economic development in 2005 and 2014 years

Types / Region	Agrarian-bioresource		Raw-material		Industrial		Trade-financial		Budget-dependent		Diversified	
	2005	**2014**	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**
Altai Krai											+	+
Amur Region							+	+				
Arkhangelsk Region			+	+								
Astrakhan Region				+	+							
Belgorod Region		+	+		+							
Bryansk Region											+	+
Vladimir Region					+	+						
Volgograd Region											+	+
Vologda Region					+	+						
Voronezh Region		+						+			+	
Moscow							+	+				
Saint Petersburg							+	+				
The Jewish Autonomous Region	+						+	+	+	+		

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

Zabaykalsky Krai							+	+	+	+		
Ivanovo Region					+				+			+
Irkutsk Region				+							+	
The Kabardino-Balkar Republic	+	+								+		
Kaliningrad Region											+	+
Kaluga Region						+					+	
Kamchatka Krai	+	+							+	+		
The Karachay-Cherkess Republic	+	+							+	+		

APPENDIX A (Continuation 1)

Kemerovo Region			+	+								
Kirov Region											+	+
Kostroma Region	+				+							+
Krasnodar Krai								+			+	
Krasnoyarsk Krai				+	+	+						
Kurgan Region											+	+
Kursk Region	+	+	+		+	+						
Leningrad Region					+	+		+				
Lipetsk Region					+	+						
Magadan Region			+	+					+	+		
Moscow Region					+		+	+				
Murmansk Region											+	+
Nizhny Novgorod Region					+	+	+	+				
Novgorod Region					+	+						
Novosibirsk Region							+	+				
Omsk Region					+	+						
Orenburg Region			+	+								
Orel Region											+	+
Penza Region											+	+
Perm Krai			+	+	+	+						
Primorsk Krai	+						+	+				
Pskov Region							+					+
The Adygea Republic	+								+			+

ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

The Altai Republic	+	+							+	+		
The Bashkortostan Republic						+					+	
The Buryat Republic							+					+

APPENDIX A (Continuation 2)

The Republic of Dagestan	+						+					+
The Republic of Ingushetia	+								+	+		
The Republic of Kalmykia	+	+										
The Republic of Karelia			+									+
The Komi Republic			+	+								
The Mari El Republic	+	+			+	+						
The Republic of Mordovia	+				+							+
The Sakha (Yakutia) Republic			+	+								
The Republic of North Ossetia-Alania	+	+					+		+	+		
The Republic of Tatarstan			+	+								
The Tyva Republic									+	+		
The Khakassia Republic											+	+
Rostov Region											+	+
Ryazan Region											+	+
Samara Region					+	+	+					
Saratov Region											+	+
Sakhalin Region			+	+	+							
Sverdlovsk Region					+	+	+	+				
Smolensk Region											+	+
Stavropol Krai											+	+
Tambov Region		+									+	
Tver Region											+	+
Tomsk Region			+	+								
Tula Region					+	+						
Tyumen Region			+	+								

APPENDIX A (Continuation 3)

The Republic of North Udmurtia			+	+	+							
Ulyanovsk Region											+	+
Khabarovsk Krai								+			+	
Chelyabinsk Region					+	+						
The Chechen Republic									+	+		
The Republic of Chuvashia	+				+							+
Chukotka Autonomous Region				+	+				+			
Yaroslavl Region					+	+	+	+				
Total	**16**	**11**	**15**	**16**	**26**	**18**	**16**	**15**	**13**	**11**	**24**	**26**

Source: based on authors' estimations.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

Appendix B

Cores of groups of one-type regions

Types of regions	Regions
Diversified	Altai Krai, Bryansk Region, Volgograd Region, Kaliningrad Region, Kirov Region, Kurgan Region, Murmansk Region, Orel Region, Penza Region, The Khakassia Republic, Rostov Region, Ryazan Region, Saratov Region, Smolensk Region, Stavropol Krai, Tver Region, Ulyanovsk Region
Industrial	Vladimir Region, Vologda Region, Krasnoyarsk Krai, Kursk Region, Leningrad Region, Lipetsk Region, Nizhny Novgorod Region, Novgorod Region, Omsk Region, Perm Krai, The Mari El Republic, Samara Region, Sverdlovsk Region, Tula Region, Chelyabinsk Region, Yaroslavl Region
Budget-dependent	The Jewish Autonomous Region, Zabaykalsky Krai, Kamchatka Krai, The Karachay-Cherkess Republic, Magadan Region, The Altai Republic, The Republic of Ingushetia, The Republic of North Ossetia-Alania, The Tyva Republic, The Chechen Republic
Agrarian-bioresource	The Altai Republic, Kamchatka Krai, The Karachay-Cherkess Republic, The Republic of North Ossetia-Alania, The Mari El Republic, The Kabardino-Balkar Republic, The Republic of Kalmykia, Kursk Region
Raw-material	Arkhangelsk Region, Kemerovo Region, Magadan Region, Orenburg Region, The Komi Republic, The Sakha (Yakutia) Republic, The Republic of Tatarstan, Sakhalin Region, Tomsk Region, Tyumen Region, Udmurtia
Trade-financial	Amur Region, Moscow, Saint Petersburg, The Jewish Autonomous Region, Moscow Region, Nizhny Novgorod Region, Novosibirsk Region, Primorsky Krai, Sverdlovsk Region, Yaroslavl Region, Zabaykalsky Krai

Source: based on authors' estimations.

References

[1] International Energy Agency 2017, Energy Efficiency 2017. URL: https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf. (Accessed 20 September 2018).
[2] Makarov, AA, Grigoryev, LM & Mitrova, TA (eds.) Forecast of the Development of World's and Russia's Energy – 2016, Institute of Energy Research, RAS & Analytical Centre at the Government of the Russian Federation, Moscow, 2016. URL: http://ac.gov.ru/files/publication/a/10585.pdf. (in Russian). (accessed 1 September 2018).
[3] Ivanov, AS & Matveev, IE, The World Energy Market Under Geopolitical Realities on the Eve of 2017, Russian Foreign Economic Journal, 1, 2017, 17-31. URL: http://www.rfej.ru/rvv/id/b0024d9d4/$file/17-31.pdf. (in Russian). (accessed 10 September 2018).
[4] Naess-Schmidt, S, Hansen, MB & von Below, D, Literature Review on Macroeconomic Effects of Energy Efficiency Improvement Actions, D6.1 report, COMBI, Copenhagen, September 2015. URL: https://combi-project.eu/wp-content/uploads/2015/09/D6.1.pdf. (accessed 20 September 2018).
[5] Saldanha, GC, Gouvea da Costa, SE & de Lima, EP, Energy Efficiency Frameworks: a Literature Overview, 27th Annual Conference Proceedings: Production and Operations, Management Society (POMS), 2016. URL: https://www.pomsmeetings.org/ConfProceedings/065/Full%20Papers/Final%20Full%20Papers/065-0440.pdf. (Accessed 20 September 2018).

ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

[6] Inshakov, OV, Bogachkova, LYu & Popkova, EG, Energy Efficiency as a Driver of Global Competitiveness, the Priority of the State Economic Policy and the International Collaboration of the Russian Federation, Energy Sector: A Systemic Analysis of Economy, Foreign Trade and Legal Regulations, Lecture Notes in Networks and Systems, 44, 2019, 119-134. DOI https://doi.org/10.1007/978-3-319-90966-0_9.
[7] EU 2014, Energy Economic Developments in Europe. URL: http://ec.europa.eu/economy_finance/publications/european_economy/2014/pdf/ee1_en.pdf
[8] Bury OV, Kalinina, AA, Kukresh, LYa, et al. Energy-economic forecasting of the development of the region, Problems of the North, Komi Scientific Center, Moscow, 2008, 365. (in Russian)
[9] Golovanova, LA & Ivanchenko, OG, Energy-economic Approach to the Regulation of Industrial Production Development, Bulletin of the Pacific State University, 1, 2010, 109-119. (in Russian). URL: http://pnu.edu.ru/media/vestnik/articles/366.pdf.
[10] Economic Glossary of Terms and Concepts. URL: http://ekslovar.ru/slovar/r-/razvitie-ekonomicheskoe.html. (accessed 20 September 2018).
[11] Khurshudyan, SG, Development of Tools for Analyzing the Effectiveness of Public Policy of Energy Efficiency in the Regions of the Russian Federation: PhD thesis, Volgograd, 2017. (in Russian)
[12] Ang, BW & Zhang FQ, A survey of index decomposition analysis in energy and environmental studies, Energy, 25, 2000, 1149-1176.
[13] Ang, BW & Zhou P, Accounting Framework for Tracking Energy Efficiency Trends, Energy Economics, 32, 2010, 1209-1219.
[14] Bashmakov, IA & Myshak, AD, Russian Accounting System for Improving Energy Efficiency and Energy Saving, Moscow: CENEF; 2012, 81. URL: http://www.cenef.ru/file/Indexes.pdf. (in Russian). (accessed 20 September 2018)
[15] Tian Goh & Ang, BW, Tracking Economy-Wide Energy Efficiency Using LMDI: Approach and Practices, Energy Efficiency, May 2018. URL: https://www.springerprofessional.de/en/journal-12053-onlinefirst-articles/11803478?pageNo=3&collectionId=11803478. (accessed 20 September 2018)
[16] Ang, BW, and Decomposition Analysis for Policymaking in Energy: Which Is the Preferred Method? Energy Policy, 9 (32), 2004, 1131-1139.
[17] Charnes, A, Cooper, WW & Rhodes, E, Measuring the efficiency of decision making units, European Journal of Operational Research, 2, 1978, 429-444.
[18] Fanyi Meng, Bin Su & Yang Bai, Rank reversal issues in DEA models for China’s regional energy efficiency assessment, Energy Efficiency, October 2018. DOI: 10.1007/s12053-018-9737-2/
[19] Bangzhu Zhu, Bin Su & Yingzhu Li, Input-output and Structural Decomposition Analysis of India's Carbon Emissions and Intensity, 2007/08 – 2013/14, Applied Energy, 230, 2018, 1545-1556. DOI: 10.1016/j.apenergy.2018.09.026
[20] Jenne, CA & Cattell RK, Structural Change and Energy Efficiency in Industry, Energy Economics, 2 (5), 1983, 114-123.
[21] Farla, J, Cuelenaere, R & Blok K, Energy Efficiency and Structural Change in the Netherlands, 1980–1995, Journal of Industrial Ecology, 20 (1), 1998, 1-28. DOI: 10.1016/S0140-9883(97)00021-2.
[22] Acharya, S & Dash, U, Energy Efficiency and Structural Change in India during 1996-2002: A Divisia Index Approach, Panjab University Research Journal (Arts), 2 (XXXIII), 2006.
[23] Haas, Ch & Kempa K, Directed Technical Change and Energy Intensity Dynamics: Structural Change vs. Energy Efficiency, The Energy Journal, 39, 2018. DOI: 10.5547/01956574.39.4.
[24] Ministry of Energy of the Russian Federation (2015), State Report on Energy Saving and Energy Efficiency in the Russian Federation in 2014. URL: https://minenergo.gov.ru/node/5197. (in Russian). (Accessed 1 October 2018).

 ISSN: 2454-1907
DOI: 10.5281/zenodo.2527617

[25] Ministry of Energy of the Russian Federation (2016), State Report on Energy Saving and Energy Efficiency in the Russian Federation in 2015. URL: https://minenergo.gov.ru/node/5197. (in Russian). (Accessed 1 October 2018).
[26] Ministry of Energy of the Russian Federation (2017a), State Report on Energy Saving and Energy Efficiency in the Russian Federation in 2016. URL: https://minenergo.gov.ru/node/5197. (in Russian). (Accessed 1 December 2018).
[27] Ministry of Energy of the Russian Federation (2018), State Report on Energy Saving and Energy Efficiency in the Russian Federation in 2017. URL: http://economy.gov.ru/minec/about/structure/depGostarif/201812103. (in Russian). (accessed 1 December 2018).
[28] Ministry of Energy of the Russian Federation (2017b), Energy Strategy of Russia for the Period up to 2035 [Draft]. URL: https://minenergo.gov.ru/node/1920. (in Russian)
[29] Bogachkova, LYu & Khurshudyan, SG, Quantitative Analysis of Energy Efficiency Indices in the Regions of the Russian Federation as Exemplified by Energy Consumption, International Journal of Energy Economics and Policy, 4 (5), 2015, 1033-1041. URL: http://econjournals.com/index.php/ijeep/article/view/1448/863.
[30] Bogachkova, LYu & Khurshudyan, SG, Decomposition Analysis of Energy Consumption Growth Dynamics and Assessment of Efficiency Indicators in the Regions of the Russian Federation, Contemporary Economics: Problems and Solutions, 1 (73), 2016, 8-21 (in Russian). URL: https://meps.econ.vsu.ru/index.php/meps/article/view/1347. (Accessed 7 December 2018).
[31] Bogachkova, LYu & Khurshudyan, SG, The Dynamics of Aggregated Indicators of Electricity Consumption Efficiency in the Russian regions at the First Stage of Implementing the Energy Strategy of Russia for the Period up to 2030, Proceedings of the International Scientific Conference on Recent Advances in IT, Tourism, Economics, Management and Agriculture – ITEMA 2017, October 26, 2017, Budapest, Hungary, 367-377.
[32] Bogachkova, LYu & Khurshudyan, SG, The Russian Regions Differentiation with Respect to Electricity Intensity of Economy Depending on the GRP Structure: Data Analysis, Modeling and Forecasting of Economic Processes: Proceedings of the VI International Scientific and Practical Internet Conference, December 15, 2014 – February 15, 2015, Volgograd: Consult LLC, 2014, 9-17. (in Russian)
[33] Khurshudyan, SG, Typology of the Regions of the Russian Federation Based on the Structure of the GRP as a Factor of Energy Intensity of the Economy: Methodological Aspects. Science Journal of VolSU. Global Economic System, 3 (36), 2016, 66-78. (in Russian).
[34] Sivelkin, VA & Kuznetsova, VE, Statistical Analysis of the Structure of Socio-Economic Processes and Phenomena, Orenburg, 2002, 35. (in Russian)

*Corresponding author.
E-mail address bogachkova@ volsu.ru