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Energy Consumption in Regions on the Way to Sustainable Innovative Development under Crisis

Anna Vladimirovna Vinogradova[1]; Julia Anatolievna Grinevich[2]
[1]National Research Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia.
[2]National Research Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia.

Abstract
The article analyses the volume of electricity consumption in the Russian Federation and in several Russian regions. The study was held taking into consideration the statistical data from 1998 to 2019. The authors developed an economic and mathematical model showing the influence of various factors on the electricity consumption. Among the main factors, they identified the gross regional product, the gross regional product per capita, electricity prices, and the exchange rate. They also draw conclusions about the significance of the factors included into the model that influence on the amount of energy consumed. An overview of approaches to the analysis of factors affecting the volume of energy consumption is made. The influence on the process of sustainable innovative development is determined, and a balanced approach to improving the energy efficiency of the domestic economy is proposed.

Key-words: Energy Consumption, Sustainable Development, Crisis, Regression Analysis.

1. Introduction

The current period of economic development is taking place in the frame of high price volatility in the energy market caused by price and trade wars. At the same time the coronavirus pandemic has led to an economic decline in production and consumption. According to Bloomberg, the current crisis has the largest scale since the great depression. The global GDP (Gross domestic product) can lose about $5.5 trillion, that corresponds to the production output in Japan [1].

The problems of sustainable development attract more attention of international organizations, they are recorded in the documents of the World Trade Organisation, the World Bank, the International Monetary Fund, the Organisation for Economic Co-operation and Development and in corporate reports. The United Nation members set 17 sustainable Development goals for the next 10

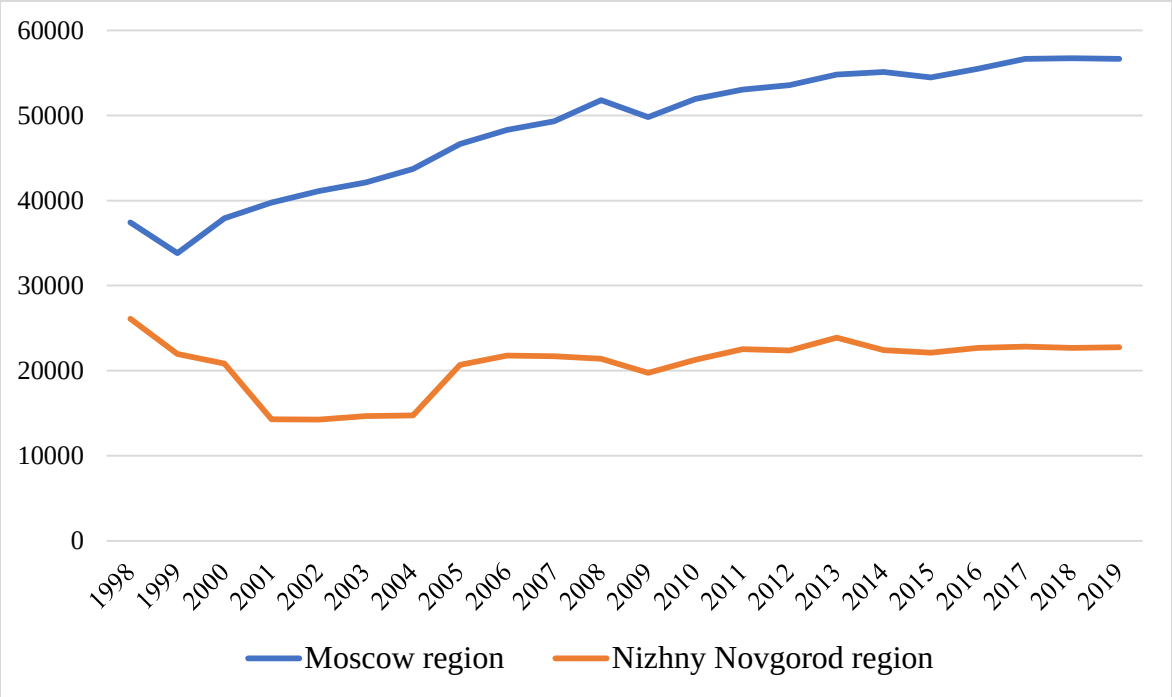
years in September 2015. [2]. The new challenges complicate the process of sustainable innovative development and require an increasingly balanced approach to improving the energy efficiency of the domestic economy. Scientists search for sustainable production and consumption models. According to Schlichter, the success depends on the development and implementation of innovative solutions, which require the active involvement of not only States, but also financial, technological and expert resources of the private sector, that is one of the most important drivers of sustainable development [3].

2. Methods

The study of energy consumption was held taking into consideration the statistical data of the Russian Federation and several Russian regions for 20 years (from 1998 to 2019). As the studied factors affecting the volume of energy consumption in Russian regions, it was proposed to take the GRP (gross regional product), GRP per capita, the exchange rate, electricity prices.

3. Results

Figure 1- Electricity Consumption in Two Regions of the Russian Federation (Million kWh)



The electricity consumption in the Russian Federation and in its regions is developing dynamically (figure 1). So, the following factors like GRP and GRP per capita were chosen for

analysis. Besides, the cost of energy resources has a significant impact, despite the fact that the demand for this resource is inelastic. The statistical significance of this factor is not unambiguous for different regions of Russia. It should be noted that this indicator should be considered taking into account the strong volatility of the national currency exchange rate. Energy market in Russia and export of energy experience a strong dependence on world energy prices.

Statistical data from 1998 to 2019 were used for further analysis.

Thus, as a result of the study, we obtain a four-factor linear model for Russia and several Russian regions (formula 1):

$$Y = a + b1X1 + b2X2 + b3X3 + b4X4 + \in \quad (1)$$

X_1 – GRP, (in current prices; millions of rubles),

X_2 – GRP per capita, rubles,

X_3 – electricity prices, per 100 kWh, rubles,

X_4 – the exchange rate (the dollar to ruble exchange rate),

Y – the volume of electricity consumed by the subject of the Russian Federation (million kWh).

In present study two models (for the Russian Federation and for Moscow region) are represented (formula 2 and 3).

$$Y = 0.007X1 + 0.0093X2 + 34.17X3 - 17.06X4 + 34932 \quad (2)$$

$$Y = 0.066X1 + 0.0935X2 + 62.21X3 - 31.21X4 + 102802 \quad (3)$$

The econometric models received by authors are acceptable. All coefficients in the models are statistically significant, and there is no multicollinearity. The models can be used in practice for planning energy supply to consumers.

The results showed that for the regions with the highest amount of electricity consumption, such as Moscow, St. Petersburg, and the Tyumen region, the value of the gross regional product is the most significant parameter (Table 1).

Table 1- Consolidated Data

	Moscow region	**Russia**
$\mathbf{b_1}$	0.007***	0.066**
$\mathbf{b_2}$	0.009***	0.093**
$\mathbf{b_3}$	34.17*	62.21*
$\mathbf{b_4}$	-17.06	-31.21*
N	22	22
R2	0.98	0.85
DW	1.67	1.78

The best statistical significance result is shown by the model for Moscow region. If GRP increases by 1 percentage point (p.p.), then the increase in electricity consumption increases by 0.7 p. p., while GRP per capita gives an increase of about 0.9 p. p. The effect of the growing dollar exchange rate against the rouble shows a negative dependence on electricity consumption.

4. Discussion

At present, a number of researchers are engaged in modelling energy consumption processes and its impact on economic growth. Their research papers are presented for the country as a whole or for a certain industry, the authors consider such countries as Saudi Arabia, Malaysia, Taiwan, Indonesia, emerging economies, new industrial countries in Asia, as well as EU countries. In particular, the industrial energy demand in Saudi Arabia model was constructed and analyzed with the Structural Time Series Model [4].

Humbatova, S.I., Ahmadov, F.S. and others used autoregressive distributed lag model as a research methodology. They show the positive correlation in GDP and electric energy consumption in economy of Azerbaijan in general and in different sectors in particular. [5]

In some models authors draw attention to the impact of energy consumption on sustainable economic growth. In particular a model of simultaneous equations was constructed for developing countries with two-stage least square method. The authors found several macroeconomic factors that can affect the level of consumption energy. These factors are energy prices, gross domestic product, and exchange rates. At the same time, the authors conclude that the total energy consumption of all

sectors tends to increase, and the growth of world oil prices may lead to a decrease in energy consumption [6]. Hong, Yen and Chien also conclude that the instability of international energy prices has become a negative factor for future economic development [7].

Fernandes and Reddy analyze the relationship between economic growth and energy consumption for six Asian countries such as China, India, Indonesia, Malaysia, Philippines and Thailand using statistical and econometric techniques such as ARDL (autoregressive distributed lags) model, Johansen's Co integration test, VECM (vector error correction model), VAR (Vector Auto Regression) and Toda Yamamoto causality test. Their results are interesting and deserve attention [8].

A number of papers are devoted to the issues of efficiency and competitiveness of the energy sector. The conclusions focus on possible changes in consumption. The analysis of technological progress impact on economic development is shown. The long term forecast for the energy sector is made for a number of European countries. [9]. Filippov analyzes the influence of the technological revolution that had taken place for the last few years on the global and domestic energy industries [10].

A lot of scientific researchers focus on sustainable development issues from the perspective of energy consumption and energy efficiency. The authors draw conclusions about the impact of energy consumption on the environment and the achievement of sustainable development goals. They establish the relationship between energy consumption, emissions and economic growth for a number of Asian countries. A number of papers also present issues of environmental pollution, which is the result of increasing energy consumption [11]. It is also concluded that energy consumption has the ability to predict economic growth [12].

Alshami and Sabah test the relationship between economic growth and electricity consumption in the United Arab Emirates. Authors analyse four factors (electricity consumption per capita, GDP in current US dollars, labor force and gross capital formation) and make conclusions about their influence on growth [13].

Sustainable consumption of energy resources by industrial enterprises in the frame of digital transformation are analysed by several Russian scientists. According to them energy systems of manufacturing industries are ready for the digital transformation that can lead to the energy efficiency [14].

Special attention is paid to the negative impact of natural and man-made disasters and serious social clashes on the environment in general and on the development of the energy market in particular [15]. Some studies aim to investigate the impact of energy consumption, population size,

economic growth, urbanization, industrialization and poverty on environmental degradation in ASEAN [16].

Different estimations of the pandemic impact on the world economy lead to different forecasts of the decline in global energy consumption caused by it, although there is no fundamental research in this field, we can only mention the research held by the International energy Agency (IEA) [17].

The result of the IEA study is as follows the demand for energy in the world will decrease by 6% over the year. This is the biggest decline in the last 70 years. The demand will decrease considerably in developed countries: in the US – by 9 %, in the European Union – by 11 %. Overall, the impact of COVID-19 on global energy demand in 2020 will be more than 7 times stronger than the impact of the 2008-2009 financial crises.

The decline in economic activity in the world affects the use of all types of energy resources, but this effect, according to Mastepanov, depends on the specific structure of energy consumption. For example, gas heating of homes or electricity consumption for digital equipment remain unchanged and even develop. But jet fuel consumption for aviation has declined more than the fall in GDP [18].

The most serious consequences of the current situation are expected in the investment sphere. The annual report of the IEA World Energy Investment, published in May 2020, concluded that investment in global energy will decrease by 20% in 2020 due to the COVID-19 pandemic [19], The main expectations of experts are shown in the table 2.

Table 2- Global Energy Investment Changes in 2017-2020

Investment fields	Investments, billion US dollars			
	2017	2018	2019	2020 (assessment)
Total	1912	1914	1891	1520
Fuel extraction	850	854	854	595
Electric power industry	782	769	757	678
Energy consumption and efficiency	280	281	280	247

According to Schlichter, the key factors for sustainable development are environmental protection and social responsibility of business. This responsibility increasingly affects the management in energy supply, purchasing of raw materials, and innovative environmental technologies development and usage [3].

The effect of energy consumption was studied by William Jevons. His known paradox called the Jevons paradox says that the use of a resource and increase in its efficiency leads to the increase

in its consumption [20]. This effect we can see not only during the period of industrial revolution, but also nowadays [21, 22, 23]

Smil wrote that energy efficiency can't reduce energy consumption [24]. Before these researches we could say about energy efficiency if energy costs for production per $ 1 billion of GDP had decreased. But now such decrease can be explained by a reduction in the energy base of expanded reproduction.

A slowdown in long-run economic growth started with industrial revolution (table 3), when we could see the first steps to a shortage of energy resources [25].

Table 3- GDP Growth and Energy Consumption

Year	GDP (billion dollars, in 2011 prices)	Energy consumption (TWh)	Energy consumption by $ 1 billion GDP (TWh)
1820	1202	6263.9	5.2
2000	63 101	112 810	1.8
2015	108120	150 307.8	1.4
2050	230 000–330 000	180 000–280 000	1.2–0.6

Spiesberger suggests using the innovation vouchers in the field of energy as a tool of innovative development [26].

The potential *Growth Points* include intensified digitalization of the energy sector and the need for institutional changes in taxation in the energy sector.[27]

5. Conclusions

The provision of energy resources is a priority for modern society. It leads to economic growth and full-fledged development. Energy-saving technologies and other innovations in energy as well as the scientific research in this area should become the main vectors of development for the modern society. The combination of new technologies and energy resources has provided a civilizational leap for humanity over the past 150 years. During the XX century, the material resources production has increased eight times, and the global GDP growth was 23 times [28].

The crisis caused by the spread of infection and human morbidity covered almost all sectors of the economy all over the world; it showed that enterprises with the lowest production costs could survive. Therefore, the development of energy-saving technologies and their active implementation in the production process will increase the competitiveness of domestic products; it will allow a faster

transition from an raw material economy based on raw materials to innovative economy and sustainable development.

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