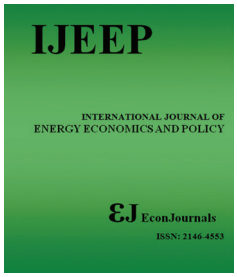

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Impact of Renewable Energy Sources Consumption on Economic Growth in Europe and Asia-Pacific Region

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ABSTRACT

Renewable energy sources have a significant impact on transforming the world fuel and energy balance structure, exacerbating inter-fuel competition. The development of green energy and a low-carbon economy is a priority task of modern energy and foreign economic policy in many countries. However, the consumption of renewable energy is uneven. This is due to the high cost of technologies and equipment and certain «distrust» in alternative fuels and their capabilities. In a framework of this study, the authors evaluated the impact of renewable energy sources on the economic development of Europe and the Asia-Pacific region, which are the primary consumers of these types of energy. The article investigates the dependence of GDP growth on the growth in consumption of fossil and renewable energy sources both in aggregate form and individual types of energy. The detailed calculations made it possible to identify the degree of influence of renewable energy on the economy in several macro-regions and determine the most significant types of energy resources. This statistically confirmed the positive impact of wind energy in Europe and solar energy in the Asia-Pacific region. The obtained regression estimates confirm the positive influence and stimulating effect of renewable energy on Europe and the Asia-Pacific region. The results obtained by the authors are based on data for the period from 1990 to 2017.

Keywords: Renewable Energy Sources, Fossil Fuel, Hydrocarbons, Economic Growth, Europe, Asia-Pacific Region, Panel Data Analysis
JEL Classifications: C23, C33, Q2, Q21, Q43

1. INTRODUCTION

Economic growth, population growth, expansion of the vehicle fleet, organization of new industries and climate change are the main drivers of increased energy worldwide consumption. The amount of global primary energy consumption in 2019 amounted to more than 14.0 billion tons of oil equivalent. At the same time, emissions of pollutants are also growing, which aggravates environmental problems. Therefore, developing «green» energy and a low-carbon economy is the priority task of current energy policy in many countries.

Countries develop a low-carbon energy complex to combat rising carbon dioxide emissions. One of the leading energy policy directions is developing renewable energy sources, which are inexhaustible and environmentally friendly. These usually include energy from the sun, wind, biomass, geothermal energy, etc. The increase in consumption of renewable energy sources in 2019 amounted to more than 15%, the total number of installed capacity of wind turbines - more than 560 GW, and solar stations - about 500 GW (BP Statistical Review of World Energy, 2019).

On the one hand, solving environmental problems requires high costs for developing energy-efficient technologies to operate treatment facilities and renewable energy facilities. On the one hand, solving environmental problems requires high costs for developing energy-efficient technologies to operate treatment facilities and renewable energy facilities. Also, renewable energy

capacity is still insufficient to meet the electricity demand fully, and seasonal fluctuations accompany generation. On the other hand, the support of ecology in clean sectors of the economy stimulates the development of science and technology, creates additional jobs, and reduces the economy's energy intensity. Also, due to the tightening of requirements for product safety, companies using safe technologies gain additional competitive advantages in the market (Makarov, 2016). Thanks to renewable energy sources, countries are becoming less dependent on imports of hydrocarbons. This fact increases their energy security and reduces risks during energy crises (Sheina and Rirozhnikova, 2016). Due to many contradictions, the exact nature of the relationship between the consumption of renewable energy resources and economic growth has not been established and is an urgent research problem.

Thus, the study of the dependence of economic growth on renewable energy is an essential scientific task that will identify the critical directions of development of world energy, determine the achievable results and evaluate the effectiveness of the environmental policy.

The purpose of this study is to assess the impact of energy factors on the economic growth of the countries of Europe and the Asia-Pacific region as leaders and active agents of greening the world economy.

2. REVIEW OF RELEVANT LITERATURE

In practice, many countries express concern that if the consumption of traditional energy sources is reduced, they will face energy shortages to ensure and achieve the planned economic indicators. However, in the scientific community, the opposite opinion is also widespread: renewable energy can create positive economic impulses and effectively replace fossil fuels. Renewable energy contributes to sustainable development, having a multiplier effect on the economy and the social sphere. Therefore, its development should stimulate economic growth, not restrain it.

Since the beginning of the 2000s, scientific research devoted to analyzing and modeling the relationship between economic growth and renewable energy has become highly relevant. Currently, the prevailing point of view is that renewable energy in the long term should positively impact economic growth since its development strengthens the energy system, leading to a decrease in dependence on imports of hydrocarbons and a reduction in harmful emissions. However, the pace of development of renewable energy depends on many factors and conditions that countries have.

At the moment, there are several hypotheses about the dependence of the gross domestic product (GDP) and the consumption of renewable energy: the hypothesis of neutrality; savings hypothesis; growth hypothesis; feedback hypothesis (Marinas et al., 2018, p. 159).

Table 1 describes all four hypotheses in detail and presents the authors' works, in which these assumptions were studied and proven.

Table 1: Analysis of hypotheses of the relationship between GDP and RES

Hypothesis	Description of the hypothesis	Researchers
The neutrality hypothesis	There is no causal relationship between real GDP and alternative energy consumption	Menegaki (2011), Vaona (2012), Payne (2009)
Savings hypothesis	Unidirectional communication from economic growth to energy consumption; increased economic activity leads to an increase in alternative energy consumption	Menyah and Wolde-Rufael (2010), Ocal and Aslan (2013), Sadorsky (2009), Lise and Van Montfort (2007)
Growth hypothesis	Energy consumption affects economic growth; the possibility of negative dependence of factors is also not rejected	Bhattacharya (2014), Inglesi-Lotz (2016), Bilgili and Ozturk (2015)
Feedback hypothesis	Real GDP and energy consumption are interdependent, i.e., a change in one factor leads to a change in the other	Apergis and Payne (2010), Lin and Moubarak (2014), Shahbaz (2015)

Source: (Armeanu et al., 2017, p. 387)

In the article of Marinas 48 studies were analyzed. According to the results, 29% of researchers found confirmation of the impact of renewable energy sources consumption on GDP; 27% found confirmation of the feedback hypothesis; 23% found confirmation of the savings hypothesis; the rest did not find any relationship between these two factors (Marinas et al., 2018).

One of the first researchers investigating the relationship between alternative energy consumption and economic growth was Sadorsky, who published two works on this topic. In his article, the linear dependence of the consumed alternative energy per capita on the real GDP per capita is considered. Sadorsky also introduced a second variation of the model, which added energy prices. To build the model, he took a dataset from 1994 to 2003 for 18 developing countries. As a result, it was revealed that a slight increase in GDP per capita leads to a significant increase in the consumption of alternative energy per capita (Sadorsky, 2009). Other Sadorsky studies also confirm a positive relationship between renewable energy and the economy (Sadorsky, 2009; 2011).

Simultaneously with the work of Sadorsky, studies were published by other authors - N. Apegis and J. Payne. Their research tested the hypothesis that renewable energy, like other factors of production, has a positive effect on GDP and economic growth. The authors used data from 1992 to 2007 for 13 countries whose economies heavily depend on oil to study this relationship. The authors describe GDP as a linear function of real gross capital formation, labor force and alternative energy consumption. During the model testing, statistically significant coefficients were obtained that proved the positive impact of labor, capital and renewable energy on real GDP (Apergis and Payne, 2010). Thus, the study confirmed the feedback hypothesis, i.e. on the existence of a two-way relationship between energy consumption and GDP.

The main purpose of the work of Omri and Nguyen is to analyze the dependence of renewable energy consumption on various energy factors: the volume of carbon dioxide pollution, energy

prices, GDP and the indicator of economic openness (Omri and Nguyen, 2014). For this analysis, the authors use dynamic regression based on a panel data approach. This research work is one of the first studies to model carbon dioxide emissions impact on renewable energy. As a result, a statistically significant positive dependence of GDP and carbon dioxide levels on renewable energy consumption was found.

The study of Ntanos examines the impact of renewable energy on economic growth for European countries. The authors suggest that the positive impact of renewable energy exists only for countries with high GDP. In this article, European countries were divided into clusters, and then vector regressions were constructed for each group to study the dependence of GDP on the size of the labor force, gross fixed capital formation (GFCF), consumption of renewable and traditional energy (Ntanos et al., 2018). The study used data from 25 European countries for the period from 2007 to 2016. During the testing of the model, a positive relationship between GDP and renewable energy was revealed for two clusters.

The influence of energy consumption of renewable energy sources on the rate of economic growth is considered in the study of Inglesi-Lotz. GDP was chosen as the dependent variable, and the number of the labor force, GFCF, science intensity of GDP and consumption of renewable energy sources were chosen as independent variables (Inglesi-Lotz, 2016). As a result of modeling, the author revealed that with an increase in the volume of alternative energy consumption by 1%, GDP would increase by 0.022%.

The article of Nguyen and Kakinaka examined the relationship between alternative energy and carbon dioxide emissions. Consumption of renewable energy sources (RES) was chosen as a dependent variable, and real GDP, real oil prices and carbon dioxide emissions were chosen as independent variables. The authors of the study constructed regression for 107 countries, divided into three groups by income level. During the testing of the model, they obtained the following results (Nguyen and Kakinaka, 2019):

1. In low-income countries, the relationship between RES consumption is negatively dependent on GDP and positively dependent on carbon dioxide emissions
2. In high-income countries, alternative energy consumption is positively dependent on real GDP, but negatively on carbon dioxide emissions
3. In middle-income countries, the dependence is the same as in rich countries, but the coefficients are much lower.

A study by Saidi and Omri (2020) found a positive two-way relationship between consumption of renewable energy and economic growth in the short and long term in 15 countries that are the main consumers of renewable energy. However, renewable energy sources affect carbon dioxide emissions only in the short term perspective (Saidi and Omri, 2020). Researchers Shahbaz, Raghulta and others expanded the sample to 38 renewable energy consumer countries and also found a two-way relationship between economic growth and renewable energy. The authors propose to strengthen international cooperation in the field of renewable energy to accelerate the fight against greenhouse gases (Shahbaz et al., 2020).

A positive impact of renewable energy sources on the economy has been identified in other scientific works (Gan and Smith, 2011; Aissa et al., 2014; Marques et al., 2018; Andini et al., 2019; Papiez et al., 2019). Some authors have proposed policy directions to increase the efficiency of renewable energy (Marques et al., 2010; Kilinc-Ata, 2016). Some authors also proved that the consumption of RES in developed countries from 1990 to 2014 led to a decrease in population income inequality (Topcu and Tugcu, 2020). At the same time, some researchers argue that the impact of increased use of renewable energy sources on economic growth in OECD countries is non-linear (Wang and Wang, 2020). A positive dependence of GDP on renewable energy was also found in the APR countries, and the feedback hypothesis was confirmed (Zafar et al., 2019).

Ohler and Fetters (2014) found a paradox: total RES consumption positively affects GDP and economic growth, while biomass energy consumption has a negative effect in the short term. The authors recommend developing hydropower, and wind energy, which use will lead to an increase in total income.

Not all studies support the positive impact of renewable energy on economic growth. For example, Chen et al. (2020) found that the positive effect of renewables occurs when their consumption in developing countries exceeds a certain level. Otherwise, renewable energy negatively affects the economy. Salim et al. (2014) found that GDP growth affects the increase in renewable energy sources consumption, and the growth of renewable energy does not change the total income. Also, Alper and Oguz (2016) could not establish a clear relationship between renewable energy and economic growth in developing countries in Europe.

3. DATA AND METHODOLOGY

The results obtained by the authors are based on data for the period from 1990 to 2017.

3.1. General View of the Model

Typically, when modeling the relationship between economic welfare and renewable energy, GDP is used as an indicator of economic growth, which can be viewed from the «demand» and «production» sides. Within the first characterizes demand approach, GDP is considered as a function that depends on energy resources, their prices, and the volume of carbon dioxide emissions. The second approach assumes to use the Cobb-Douglas production function to describe GDP. Also, this approach considers the consumption of alternative energy as an indicator of scientific and technological progress (Omri and Nguyen, 2014). Renewable energy is a high-tech industry that requires scientific research, advanced equipment and specially trained personnel to develop. Indeed, the country must have sufficient financial resources and scientific potential to develop renewable energy. These conditions for producing and consuming renewable energy are necessary and possible only with a high scientific and technological development level.

In this work, we will consider the dependence of GDP on the main energy carriers of the fuel and energy balance (FEB) since we expect to identify a direct effect on the economy from the use of hydrocarbon fuels, renewable energy sources, hydropower and nuclear energy. A multivariate linear regression based on panel data was chosen to analyse the impact of energy factors on GDP. We chose real GDP, calculated at purchasing power parity (PPP), as a dependent variable and included traditional and non-traditional energy resources consumption as independent variables. We will use their incremental values in the model since energy consumption and GDP growth annually. We will consider energy consumption in an aggregated form, dividing it into traditional (oil, gas and coal) and alternative (wind, solar, geothermal, nuclear energy, hydropower) types of energy in the first variation of the model. In the second variation, the impact of each type of fuel on the economy will be considered separately.

Thus, the dependence of GDP on fuel consumption will be described in the following way (1):

$$Y_{it} = \sum_{k=1}^{8} \alpha_k X_{kit} + \varepsilon_{it}, \quad (1)$$

where X_k are the variables responsible for the oil, gas, coal, solar, wind, geothermal and biomass energy, nuclear energy, and hydropower consumption; ε is a random error.

3.2. Sample of Countries

The countries of Europe and the Asia-Pacific region were selected as the main objects of research since they are leaders in the growth rates of consumption of renewable energy sources and represent a traditional and promising market for the sale of Russian hydrocarbons. Studying structural changes in the energy sector in Europe and the Asia-Pacific region will allow determining future development trajectories and predicting the need for energy resources in the selected macroregions, and substantiating recommendations for Russia's energy policy. It is advisable to divide European countries into two groups - OECD and non-OECD countries to form homogeneous groups by the level of economic development (Table 2). Lithuania, Latvia, Slovenia, which joined the union during the period under review and Slovakia with Turkey, were added to the non-OECD European countries group.

The division of European countries into groups also allows considering the heterogeneity in the level of consumption of renewable energy. So, if the countries of Western Europe annually expand the production of renewable energy sources, then in the eastern regions of Europe, this process is taking place more slowly. The countries of the Asia-Pacific region are united into one group and include not only the «Asian tigers» - Singapore, China and Hong Kong, but also countries with a lower level of economic development - Pakistan, Sri Lanka, Vietnam. Since panel regression takes into account individual effects, we will isolate a general trend that is characteristic of the entire Asia-Pacific region. Thus, the data sample can be considered representative.

Table 2: Sample of countries

The first group of European countries (Europe)	The second group of European countries (East_Europe)	APAC countries (APAC)
Austria	Azerbaijan	Australia
Belgium	Belarus	Bangladesh
Great Britain	Bulgaria	China
Hungary	Cyprus	Hong Kong
Germany	Latvia	India
Greece	Lithuania	Indonesia
Denmark	Macedonia	Japan
Ireland	the Russian Federation	Malaysia
Spain	Romania	New Zealand
Italy	Slovakia	Pakistan
Luxembourg	Slovenia	Philippines
Netherlands	Turkey	Singapore
Norway	Ukraine	South Korea
Poland	Croatia	Sri Lanka
Portugal	Estonia	Thailand
Finland		Vietnam
France		
Czech Republic		
Switzerland		
Sweden		

3.3. Choice of Model Variables

Among the traditional sources of energy, oil occupies a special place, the dynamics of production and consumption, which has the most significant influence on the conjuncture of the world energy market and many countries' economies (Eder et al., 2018; Filimonova et al., 2019). Oil consumption, in general, has a positive effect on economic growth since it is one of the main types of fuel in industry and transport (Eder et al., 2019). An increase in natural gas consumption should also have a positive effect on the growth of total income. The growth in gas consumption is due to the lowest level of pollutant emissions into the atmosphere among all fossil fuels. The economic impact of increased coal consumption can be ambiguous. On the one hand, coal is the most "non-ecological" type of fuel, and many countries are removing it from their fuel and energy balance. On the other hand, coal is one of the cheapest types of fuel, easily transported and able to meet additional energy needs for growing economies quickly.

A controversial issue is the impact of alternative energy on economic growth. Because its development requires significant investment and operating costs, there is a technological risk, i.e. the likelihood that renewables will not be able to meet additional energy needs or offset fossil fuels fully. For example, the development of the electric vehicle market is limited by the time and investment factor for the creation and expansion of production facilities, the availability and prevalence of the main components of chargers (lithium, cobalt and nickel), as well as poor infrastructure provision of territories with generating capacities and charging stations. Therefore, fossil fuels will remain the primary energy source in the long term, for example, in transport.

Nevertheless, the positive effects of RES are also noticeable - the development of high-tech industries, the creation of new jobs, an increase in our energy security and a decrease in dependence on imports of hydrocarbons (Sheina and Rirozhnikova, 2016).

The development and testing of models will allow the authors to analyze which of these processes have the most significant impact on Europe and the Asia-Pacific region economies.

3.4. Detailing Models

Table 3 shows all the designations of the models used to consider the dependence of GDP growth on the growth in consumption of various energy sources separately and in aggregate. So, Model_1, Model_2 and Model_3 assess the impact of the aggregate consumption of fossil and non-fossil fuels on the economy, and Model_4, Model_5 and Model_6 study the impact of an increase in consumption of each type of energy resource on the economy.

The research horizon covers the period from the early 1990s of the XX century to 2017. However, it is known that the active growth of renewable energy fell in 2008-2009, when, before the financial and economic crisis, the period of high prices for hydrocarbon raw materials stimulated the search for alternative fuels. Until 2008, the main consumers of renewable energy sources were the United States, Germany, Spain and Japan. Then later, this list has significantly expanded. Therefore, for a more detailed study of the influence of energy factors on GDP growth, the period under consideration is divided into two parts - 1990 - 2007 and 2008 - 2017.

Table 3: Designations of the models investigated the dependence of economic growth on energy factors

Model name	Model description
Model_1_region	Impact of consumption of fossil and non-fossil fuels on economic growth in 1990-2017
Model_2_region	Impact of consumption of fossil and non-fossil fuels on economic growth in 1990-2007
Model_3_region	Impact of fossil and non-fossil fuel consumption on economic growth from 2008-2017
Model_4_region	Impact of certain types of energy on economic growth in 1990-2017
Model_5_region	Impact of certain types of energy on economic growth in 1990-2007
Model_6_region	Impact of certain types of energy on economic growth in 2008-2017

Table 4: Results of Model_1, Model_2 and Model_3 for OECD European countries

Model	Factor	Fossil fuel	Renewable energy sources
Model_1	Coefficient	3010.80	1642.46
	Significance	0.00	0.01
	R^2	0.17	
Model_2	Coefficient	-225.15	470.76
	Significance	0.52	0.39
	R^2	0.05	
Model_3	Coefficient	3794.34	2541.14
	Significance	0.00	0.01
	R^2	0.25	

The set of proposed models will make it possible to comprehensively determine the impact of each type of fuel on economic growth for the entire period under consideration and adjust the estimate taking into account the impact of the crisis. The simulation results will help answer the following research questions:

1. Is there a positive relationship between economic growth and the consumption of renewable energy sources?
2. Has the impact of fossil fuel consumption on the economy changed in the context of growing RES consumption?
3. What energy carriers have the most significant impact on economic growth in Europe and the Asia-Pacific region?

The information base is formed from the following indicators: GDP and gross fixed capital formation (at PPP in constant 2011 prices, in US dollars), consumption of oil, gas, coal, solar, wind, geothermal, nuclear energy and hydropower (mtoe), carbon dioxide emissions (million tons), the labor force (million people). The data source is the statistical databases The World Bank and British Petroleum.

4. RESULTS

In the panel regression constructed by the authors, as described above, the dependent variable is the GDP growth, and the independent variables are the growth in the consumption of oil, gas, coal, solar energy, wind energy, geothermal, nuclear energy and hydropower, the period from 1990 to 2017. Previously, a paired regression matrix was built to test the correlation between factors, which made it possible to exclude highly correlated regressors.

Based on the initial analysis of the data, the following hypotheses were formulated, which were then tested using models:

1. The GDP growth rate positively depends on the increase in the consumption of hydrocarbon fuels both in Europe and in the APR countries
2. The consumption of renewable energy sources has a positive effect on economic growth since it increases the supply of energy to countries and creates the preconditions for the development of high-tech sectors of the economy
3. The influence of RES consumption was more pronounced in 2008-2017 than during the period 1990-2007.

Table 5: Model_4-6 results for OECD European countries

Indicator	Model_4		Model_5		Model_6	
Oil	5591.97	0.00	1002.71	0.17	10562.51	0.00
Gas	1130.11	0.04	–1320.06	0.03	554.95	0.50
Coal	3946.11	0.00	1111.98	0.07	3772.85	0.00
Solar energy	–3825.87	0.45	198266.02	0.00	18036.66	0.02
Wind energy	9316.30	0.00	3229.53	0.58	11641.54	0.00
Geothermal energy	127894.07	0.16	-47354.43	0.48	-	-
Atomic Energy	610.89	0.49	-2.47	1.00	1756.22	0.18
Hydropower	1187.08	0.12	1258.97	0.03	765.91	0.56
R^2	0.26		0.17		0.38	

In studying the influence of RES consumption on economic growth in European countries, the authors constructed a linear regression using the least-squares method (OLS) and a model with fixed effects and a model with random effects. According to Fisher's test, all regressions were found to be significant, i.e. there is a statistically proven relationship between the selected factors. We carried out tests to compare the three obtained regressions alternately to select the most statistically significant regression (Table 4).

Test results indicated that fixed effects regression should be chosen. Model_1_Europe became an exception since the Hausman test allows the use of regression with random effects. In other cases, although the model with random effects is significant, the Hausman test confirms zero correlation between personal effects and regressors. Therefore, we will use a fixed-effects model for further analysis. Also, in Model_6_Europe, a correlation was found between wind and geothermal energy. The correlation leads to a bias in the estimates, so geothermal energy consumption was excluded from the equation (Table 5).

According to the values of the obtained coefficients in the regression equation, the GDP of European countries positively depends on the consumption of oil, gas and coal in Model_4_Europe. Also, GDP positively depends on the consumption of wind energy in Model_4_Europe and Model_6_Europe. Indeed, during 2008-2017, wind energy developed at a faster pace than solar. In 2017, wind energy consumption amounted to 28.1 million tonnes of oil equivalent, and more than 178 thousand wind turbines were installed. The influence of solar energy consumption was not significant in Model_4_Europe. However, in Model_6_Europe it is significant and positive. This is due to the fact that since 2008 European countries have begun to actively develop solar energy and receive a return on investments in it. Due to climatic conditions, the use of wind energy is more profitable than solar energy.

Table 6: Results of Model_1, Model_2 and Model_3 for Asia-Pacific countries

Model	Factor	Fossil fuel	Renewable energy sources
Model_1	Coefficient	2514.61	14743.77
	Significance	0.00	0.00
	R^2	0.46	
Model_2	Coefficient	2689.07	5657.59
	Significance	0.00	0.00
	R^2	0.55	
Model_3	Coefficient	992.25	2693.68
	Significance	0.01	0.01
	R^2	0.06	

For the Asia-Pacific countries, the authors constructed six regressions and analyzed the results. It turned out that in each case, the fixed-effects model was the most preferable. All regressions with fixed effects were significant by Fisher's test, which confirms the existence of a relationship between the variables. The coefficients of the models used for the analysis of the APR countries are presented in Tables 6 and 7. In Model_4 and Model_6, we had to exclude wind energy consumption from the equation after correlation analysis since this variable was strongly correlated with natural gas and solar energy consumption.

According to the obtained results, an increase in renewable energy consumption positively affected GDP growth in the APR countries. Indeed, since the end of the twentieth century, the countries of the Asia-Pacific region have significantly modernized many sectors of the economy, strengthened the industrial sector and increased welfare, which increased their electricity demand. Since the countries of the Asia-Pacific region do not have sufficient reserves of oil and gas to meet their own needs, and they are trying to replace coal in the fuel and energy base with more environmentally friendly types of fuel, the urgent task is to develop new «green» energy sources. An increase in the consumption of renewable energy sources creates positive impulses in the economies of the APR countries, thereby stimulating economic growth.

Model_4, Model_5, Model_6 demonstrate that the APR countries are highly dependent on the growth of traditional energy sources (oil, gas and coal). The Asia-Pacific region is a world industrial centre, which requires high energy consumption to maintain. The energy demand is provided by fossil energy sources, which are more reliable and more explored. Nevertheless, the countries of the Asia-Pacific region are increasing their consumption of renewable energy sources. So in our models, a positive effect of solar energy (Model_4, Model_6), wind energy (Model_5) was found. The consumption of geothermal energy turned out to be insignificant, which may be due to the limited development of this RES due to the lack of necessary natural conditions. An increase in the consumption of atomic energy, which is significant according to the Student's criterion, positively affects the GDP of the APR countries.

The results for non-OECD European countries are presented in Tables 8 and 9. In all the models under consideration, the

Table 7: Results of Model_4, Model_5 and Model_6 for Asia-Pacific countries

Indicator	Model_4		Model_5		Model_6	
Oil	5185.37	0.00	1751.16	0.01	5832.20	0.00
Gas	20423.18	0.00	18694.36	0.00	4971.37	0.00
Coal	1415.71	0.00	1661.27	0.00	454.74	0.21
Solar energy	48992.68	0.00	12840.19	0.97	21892.63	0.00
Wind energy	-	-	362333.30	0.00	-	-
Geothermal energy	–29970.39	0.63	-21392.83	0.66	–24120.52	0.71
Atomic Energy	8146.16	0.00	5953.16	0.00	3640.77	0.00
Hydropower	10250.88	0.00	5356.92	0.00	222.77	0.84
R^2	0.67		0.75		0.48	

panel regressions with fixed effects, which we will use for the analysis, became the most significant. In Model_4, Model_5 and Model_6, geothermal energy consumption had to be excluded from consideration due to the presence of a correlation with wind energy. This step should not distort the results since this type of energy is not popular among countries from the subgroup under consideration.

In European non-OECD countries, there are strong barriers to renewable energy development, so fossil fuels are mainly used. The obtained results of the models prove this since the increase in the consumption of oil, gas and coal turned out to be significant.

In Model_3, the increase in the consumption of non-fossil energy sources is insignificant. This may be due to the consideration of energy carriers in an aggregated form. For example, some of the countries in the sample reduced their nuclear and hydropower consumption in 2008-2017, but they began to increase their wind and solar capacity during the same period. For example, in Model_5, covering the period up to 2007, nuclear and hydropower were significant regressors from unconventional energy sources. However, already in Model_6 these variables became statistically insignificant. As we can see, Model_4 proves a positive relationship between wind power gain and economic growth. The influence of solar energy was not significant. This was to be expected, because wind energy is more affordable and profitable in European countries, and thanks to the development of technologies, the cost of wind energy has significantly decreased.

5. DISCUSSION

As a result of the study, a positive dependence of the economies of European and the Asia-Pacific region countries on the consumption of renewable energy sources was found. In addition, the regional specification found based on the primary data analysis was confirmed, i.e. European countries are more influenced by wind energy than solar. Indeed, electricity generated by wind power intensifies competition with other types of energy carriers in European countries and can influence energy price fluctuations. For example, in 2020, Finland, Denmark, Germany, and the UK all saw hostile energy prices as the storm increased wind turbine generation. This situation shows that the capacity of wind farms can significantly increase the supply of energy. However, this happens only during favourable stormy weather, so the problem of accumulating excess energy remains relevant and still slows down the development of renewable energy. Solar energy turned out to be significant in the Asia-Pacific countries and has a positive effect on economic growth (Model_4 and Model_6). No statistically significant relationship between GDP growth and consumption of geothermal energy was found for either Europe or the Asia-Pacific region.

Solar energy sources make a significant contribution to the growth rates of the economies of the Asia-Pacific region, according to Model_4. However, in European countries, no statistically significant estimate of the dependence of GDP on solar energy has been found. The climatic features of the countries can explain this since the Asia-Pacific region includes more southern countries (Australia, India, Thailand, Malaysia, etc.). For example, the Nordic countries are limited due to natural features in the development of solar energy and, when creating a single European energy base, they would have to export the energy generated by this renewable source. In 2017, there were 114 thousand operating solar stations in Europe, and more than 200 thousand were installed in the APR countries (BP Statistical Review of World Energy, 2019).

Of course, it is not surprising that economic growth is positively dependent on the consumption of fossil fuels. Expansion of the economy requires large energy resources expenditures, and fossil fuels continue to play the leading role in the global energy balance. Despite the accelerated pace of development of renewable energy, traditional energy sources are in the lead. Still, the process of replacing traditional forms of energy with renewable ones is quite tricky, especially in sectors that are heavily dependent on hydrocarbons. For example, in the transport sector, which usually consumes one-third of the country's total energy, the share of petroleum products in the consumption structure is about 90%, so it is not easy to replace them with biofuels or electric motors in the near future. Mainly, the energy obtained from renewable energy sources is used for servicing households, services and agriculture. However, solving global environmental problems

Table 8: Model_1, Model_2 and Model_3 results for non-OECD European Countries

Model	Factor	Fossil fuel	Renewable energy sources
Model_1	Coefficient	5002.26	3787.34
	Significance	0.00	0.01
	R^2	0.44	
Model_2	Coefficient	4238.27	9644.25
	Significance	0.00	0.00
	R^2	0.47	
Model_3	Coefficient	5311.37	-1310.38
	Significance	0.00	0.50
	R^2	0.55	

Table 9: Model_4, Model_5 and Model_6 results for non-OECD European countries

Indicator	Model_4		Model_5		Model_6	
Oil	7426.88	0.00	7958.30	0.00	7862.99	0.00
Gas	4053.09	0.00	1806.90	0.00	4750.95	0.00
Coal	4640.00	0.00	6733.90	0.00	3959.69	0.00
Solar energy	–27509.27	0.62	8269400.00	0.94	–18928.36	0.74
Wind energy	55482.70	0.02	6022.70	0.99	51203.10	0.11
Geothermal energy	-	-	32000.00	0.96	-	-
Atomic Energy	6873.53	0.03	11083.00	0.00	-1658.61	0.73
Hydropower	303.89	0.88	4857.60	0.08	-2895.96	0.25
R^2	0.47		0.57		0.57	

is becoming a priority task for the world community. So many countries strive to reduce traditional fuels consumption and carbon dioxide emissions. European countries are a kind of target point since they are developing advanced treatment technologies, and they were also the first to develop renewable energy actively. In addition, the level of prosperity of the European region proves that the use of renewable energy does not harm economic growth.

6. CONCLUSION

Sustainable economic growth in modern conditions is impossible without a developed and reliable energy complex. Energy consumption is growing every year as production expands, households are more equipped with technology, and the motorization process is accelerating. In 2019, energy consumption exceeded 14.0 billion tones of oil equivalent. More than 80% of total energy consumption came from fossil fuels - oil, gas and coal. However, renewable energy is actively developing, which is becoming more affordable thanks to the improvement of equipment. Wind and solar energy became widespread. Their total consumption amounted to about 420 million tons of oil equivalent. The leaders in the consumption of renewable energy sources are China and the USA and the countries of Europe and the Asia-Pacific region.

Evaluation of the effectiveness, prospects and risks of economic policy is becoming an increasingly urgent research task. Special attention is paid to renewable energy, which should become a driver of an ecological and safe future. A review of the scientific literature showed that the exact relationship between economic growth and renewable energy had not been found, and there are four hypotheses about the nature of their relationship. Researchers tend to believe that there is a two-way relationship between GDP and the volume of consumption of renewable energy. To describe this relationship, we used two models: a demand-side model and a production-side model. The demand model examines how environmental factors and fuel prices have affected GDP. In the second method, the Cobb-Douglas function is used, and renewable energy sources' volume is considered technical progress.

To determine the nature of the dependence of economic growth and renewable energy sources, the authors used the model of inter-fuel competition, which considers the impact of all energy sources on economic growth.

Using panel regression, the authors estimated the dependence of GDP, calculated in PPP, on oil, gas, coal, solar, wind, geothermal, nuclear energy and hydropower consumption. European countries have been divided into OECD and non-OECD countries. As a result of model testing, it turned out that both groups of European countries are positively dependent on wind energy, and the effect of solar energy turned out to be statistically insignificant. The APR countries, on the other hand, are positively dependent on solar energy. In all considered regions, GDP growth is accompanied by an increase in the consumption of fossil fuels.

The results obtained prove that the considered regions are becoming more energy efficient. Regression estimates prove that the development of renewable energy creates positive impulses and leads to real GDP growth. This is due to the stimulation of scientific progress, the creation of new high-tech sectors of the economy, and jobs creation. Also, the countries are getting additional own energy resources that meet the growing energy demand. In European countries, it is beneficial to expand wind energy capacity due to favorable weather conditions. In the countries of the Asia-Pacific region, both solar and wind energy create positive effects. This can be explained by the fact that Asian countries have a higher demand for energy, which they need both for the functioning of the industry and for serving the needs of the population.

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