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Multifactorial Components Analysis of the Renewable Energy Sector in the OECD countries

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Abstract

New technologies and new market realities determine the global energy industry to redesign their business models in all significant areas. We based our research on the components of renewable energy within the OECD countries and used thirteen indicators in order to find out both the relations and the impact of main sectorial indicators and the global indicators of the OECD countries to their economic and social development. The main goal of our research is to discover the main correlations between the renewable energies and the economic development of the OECD countries. We used databases of the OECD, Our World in Data, International Energy Agency (IEA) and International Renewable Energy Agency (IRENA), available for years 2017 and 2018. We apply Principal Component Analysis (PCA) and retain three principal components explaining 76.098% of the total variance. The main findings of the PCA application are; (1) factor 1 is dominated by the main renewable energy sources: traditional biofuels, hydropower, solar, wind and other renewables, as well as energy products, energy exports, energy capacity and energy generation; (2) factor 2 is dominated positively by energy imports and negatively by primary energy supply and GDP per capita; (3) factor 3 measures electricity generation. The results are addressed to the OECD member states, but also to other categories of states. Our results clearly show whetherthe OECD states are developing coherent renewable energy policies as part of an integrated smart energy system. The results show a direct link between investments in renewable energy and macroeconomic indicators of the considered states.

Keywords: renewable energy, principal component analysis, governmental policy.

JEL Classification: Q2, Q4, Q5

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1. Introduction

In the last couple of decades, environmental issues have become increasingly visible on the political agenda and have galvanised civil and political powers into action (Dan, 2019). The role of renewable energy is especially underlined. Renewable energy is a viable and sustainable alternative to fossil fuels energy for several reasons: it is inexhaustible, has a minimal effect on the environment, does not emit greenhouse gases and does not produce waste, enables a decentralized energy production adapted to the local resources and needs and offers important energy independence (Adamisin et al., 2018). In recent years, global energy consumption is growing much faster than the population. Thus, if five decades ago, at a population of 3.7 billion people, the energy consumption was of 5 billion tons of oil equivalent, by 2020 it is estimated that it will reach 8 billion people, and the energy consumption will reach 19 billion tons of oil equivalent. By 2040, there will be about 9 billion people on the planet, and consumption will be more than 6 times higher (32 billion tons) than 50 years ago. Between 2060 and 2065, the global population will reach 10 billion people, and energy consumption will continue to grow.

The pressure generated by increased demand and concern about climate change will have an impact on all segments of the energy, utilities, and resources industries (Zhang et al., 2016). The energy sector is at the centre of massive transformations (Droes & Koster, 2020). The growing demand for energy, associated with the decline of oil, gas and coal resources, is driving up prices for conventional energy (Sabishchenko et al., Haseeb et al., 2020). Governments around the world have responded by setting goals for generating "clean" energy and by encouraging and providing incentives for new forms of energy from renewable sources. (Dudin et al., 2019; Chehabeddine & Tvaronavičienė, 2020; El Idrissi et al., 2020; Mikhaylov et al., 2020). Investors and financial institutions should be able to accurately determine the return and return on their investments. Research shows that capital investment can provide the necessary impetus to reduce environmental degradation (Mesagan & Olunkwa, 2020). In this complex international context, the OECD plays an important role by promoting structural reforms through a social agenda focused on combating inequalities and sustainable development. The keys priorities of the OECD are the green growth indicators (Kelić et al., 2020) sustainable tourism development (Vu & Ngo, 2019) renewable energy, transportation, and many others. For more than fifty years, the OECD has been an internationally recognized authority in the field of analysis, recommendations, comparative data and economic and social statistics (Duľová Spišáková et al., 2017). The 36 members of the OECD (of which most Europeans - 24) are developed states, holding over 70% of global production and trade and 90% of the global foreign direct investment (Tkachuk & Vinnychuk, 2020).

The main goal of our research is to apply data mining techniques to reduce data dimensionality such as a main component analysis in order to find the main factors influencing (Al-Tkhayneh et al., 2019) the renewable energy consumption in OECD states during 2017-2018, such as primary energy supply, energy generation, nominal GDP per capita, energy production, energy capacity and some others (Çera et al. 2019; Žižka & Pelloneová, 2019). One of the purposes of this paper is to analyse the relationship between GDP per capita and primary energy supply.

2. Problem Statement

The Millennium Report on Ecosystems, which groups 1400 scientists within the UN, concluded that 60% of ecosystems are degraded or used in a non-renewable way. Climate change is the biggest threat to the preservation of a habitable planet.

Recent analyses carried out by the International Energy Agency (IEA) show that CO2 emissions have stagnated globally for the second consecutive year, while the global economy has grown by more than 3%. Preliminary IEA data suggests that electricity generated from renewable energy has played a critical role, accounting for about 90% of total new energy generated in 2015 (Androniceanu & Tvaronavičienė, 2019). This new decoupling trend is found in 21 states that have succeeded in reducing gas emissions by greenhouse effect simultaneously with the growth of the gross domestic product. 16 of the respective countries are the Member States in the European Union, including Romania. Renewable energy includes hydro, geothermal, wind, solar, tide and wave sources, energy derived from solid biofuels, bio gasoline, bio diesels, and so on. Renewable energy production has been dominated by biomass: wood burning and agricultural waste biomass. In 2014, renewables reached an estimated 1.7 TW (double than that of 10 years ago), and the percentage in the overall capacity of electricity generation increased to almost 23%. It is remarkable how developments in "new" renewables and non-hydro renewables capacity have increased from about 85 to over 650 GW (almost 7 times) in a decade. At the end of 2015, the worldwide capacity of wind generators was of 432 419 MW (over 432 GW), representing an increase of 17% as compared to the previous year. The countries with the largest installed capacity in wind farms at the end of 2015 are: China - 145 GW; United States - 74.5 GW; Germany - 45 GW; India - 25 GW; Spain - 23 GW. Wind energy production capacity has grown constantly worldwide, reaching 433 GW by 2015 according to the Global Status Report of Renewable Energy Network 21. In 2017, over 90% of countries have established policies and targets for reducing pollution and exploitation of renewable energy sources. Wind energy is considered as one of the most sustainable options. It is estimated that global recoverable wind energy stands at about 53000 TWh (TerraWatt/hour), which is 4 times the current global consumption of electricity. Renewable energy producers and suppliers in different countries must guarantee the reliability of their products and services. Operators must provide the necessary production capacity for their plants and operations and maximize availability and efficiency, in order to have a robust growth. According to the climate mitigation strategy at least two million megawatts of renewable energy will have to be produced over the next 40 years in order to completely and efficiently replace current coal-fired and to meet the current energy needs by 2050. This is a very important goal that has become a challenge for many countries with potential for renewable energy production. In a report published in October 2015, the International Energy Agency (IEA) predicted that renewable energy will account for 26% of global electricity production in 2020, compared to 22% in 2013. The 4 percent means the increased quality of life and accountability. It indicates a significant change in policies. According to available statistics, in the last 10 years, the production of renewable energy in the E-SRE system has increased 1000 times.

Most of the increase in energy demand comes from India and China. Renewables are the fastest growing energy source. The use of natural gas will increase much faster than that of oil or coal. Increasing population and demand for energy are putting pressure on the discovery of new resource deposits and, implicitly, on producers' investment budgets. Our research is focused on OECD member states and is aimed at policy makers with the intention of informing and inspiring them in adopting a vision consistent with the real needs of the present. Member States of the Organization for Economic Cooperation and Development (OECD) must invest over $ 7.6 trillion over the next 25 years to achieve energy policy goals, reduce emissions and create a sustainable electricity generation system. Our research is based on principal component analysis (PCA) and clustering analysis for the assessment of the renewable energies from the OECD member states.

3. Aims of the research

The main aim of our research is to find the key factors influencing renewable energy production and generation in OECD member states. This analysis is performed by means of PCA, with the purpose to extract the smallest number of principal components, according to some criteria, which will retain the most possible amount of information in the dataset.

4. Research Methods

Principal Component Analysis (PCA) is a multivariate statistical technique for reducing a dataset of interrelated variables to fewer uncorrelated principal components (PCs or factors). These new uncorrelated variables maximize the variance. PCA aim is to bring out strong patterns from large datasets (Wilks, 1995; Jolliffe, 2010). We selected 13 variables, taken from various databases: OECD, Our World in Data, International Energy Agency (IEA) and International Renewable Energy Agency (Irena), available for 2017 and 2018: Primary energy supply (toe _1000USD) (V1), Electricity generation (Gigawatt-hours) (V2), Renewable energy (Ktoe) (V3), Traditional biofuels (terawatt-hours) (V4), Hydropower (terawatt-hours) (V5), Solar (terawatt-hours) (V6), Wind and other renewables (terawatt-hours) (V7), Energy production (ktoe) (V8), Energy imports (ktoe) (V9), Energy exports (ktoe) (V10), Energy capacity (MW) (V11), Energy generation (GWh) (V12) and Nominal GDP per capita (USD) (V13).

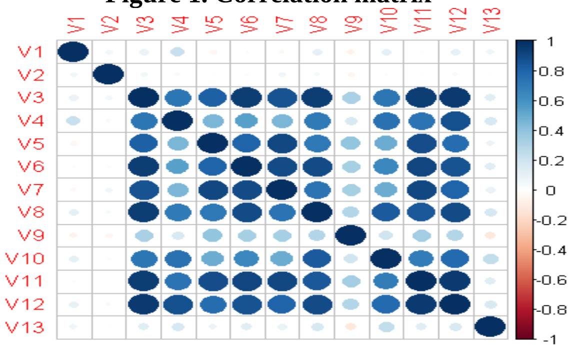
5. Findings

The first step of PCA is to observe correlations among variables. The correlation matrix among the 13 variables is represented in Figure 1. Positive correlations are represented in blue and negative correlations in red. Colour intensity and circle size are proportional to the correlation coefficients. In our case only strong and weak positive correlations are predominant. From the correlation matrix we notice the highest correlations between renewable energy and hydropower; renewable energy and energy capacity; renewable energy and energy generation.

For PCA we applied the statistical program Xlstat under Excel.

The model can be considered valid since Bartlett's sphericity test has the value of 721.879 (Sig <0.0001) and Kaiser-Meyer-Olkin measure of sampling adequacy is 0.675>0.5.

Figure 1. Correlation matrix



Source: Authors

We will perform PCA analysis on the correlation matrix in Figure 1 since the variables are measured in different units and we want to obtain factors over which all variables have a balanced impact. The 13 variables have been grouped into 3 factors with eigenvalues greater than 1, accounting for 76.098% of the total variance. Factor 1 explains 57.44% of the total variance, Factor 2 explains 10.793% and Factor 3 explains 7.866%. The informational loss is about 23.9%.

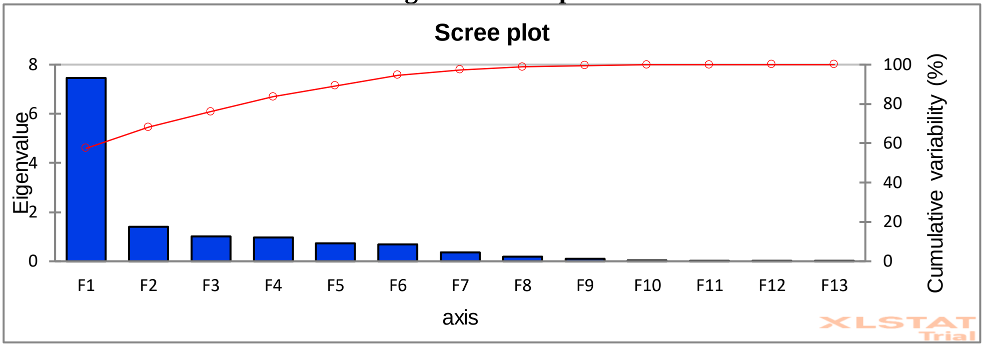
Table 1. Eigenvalues, individual variability (%) and cumulative variability (%)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
Eigenvalue	7,467	1,403	1,023	0,978	0,73	0,697	0,353	0,198	0,095	0,039	0,012	0,004	0
Variability %	57,44	10,793	7,866	7,5	5,618	5,360	2,714	1,526	0,728	0,297	0,096	0,033	0,003
Cumulative %	57,44	68,232	76,098	83,625	89,243	94,603	97,317	98,843	99,571	99,868	99,964	99,957	100

Source: Authors

Besides the eigenvalues, the scree plot (figure 2) plots the variances represented by eigenvalues against the number of factors. From the scree plot we will retain the first three factors capturing 76.098% of the information contained in the original data.

Figure 2. Scree plot



Source: Authors

The elements of the eigenvalues are the coefficients or the loadings of the factors. In table 2 we show the loadings of the three retained factors.

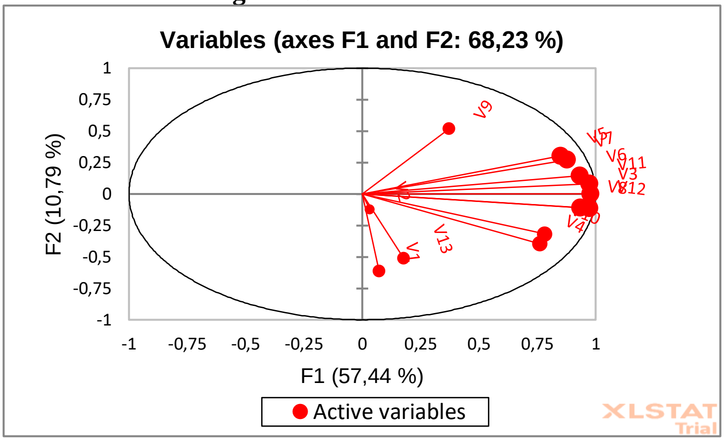
Table 2. Factor loadings

Factor loadings	Factor 1	Factor 2	Factor 3
V1	0.072	(-0.616)	0.279
V2	0.034	-0.128	(0.887)
V3	(0.980)	0.001	0.044
V4	(0.762)	-0.397	-0.008
V5	(0.850)	0.303	0.021
V6	(0.932)	0.145	-0.002
V7	(0.879)	0.271	0.068
V8	(0.936)	-0.109	-0.006
V9	0.372	(0.518)	0.060
V10	(0.784)	-0.318	-0.139
V11	(0.974)	0.081	-0.011
V12	(0.973)	-0.113	0.004
V13	0.178	(-0.513)	-0.357

Source: Authors

Loadings greater than an absolute value of 0.5 are shown in parentheses. The factors are interpreted by the magnitude and direction of the factor loadings. The larger the absolute value of the factor loadings, the bigger the impact that loading has on that factor. We extracted the most correlated variables with each factor. The main determinants of factor one are: Renewable energy (V3) with the magnitude -0.980, Traditional biofuels (V4) with -0.762, Hydropower (V5) with -0.850, Solar (V6) with -0.932, Wind and other renewables (V7) with -0.879; Energy production (V8) with -0.936, Energy exports (V10) with -0.784, Energy capacity (V11) with -0.974, Energy generation (V12) with -0.973. Thus, factor one measures the main renewable energy sources: traditional biofuels, hydropower, solar, wind and other renewables. Factor two is dominated by Primary energy supply (V1) with negative magnitude -0.616, Energy imports (V9) with positive magnitude 0.518 and GDP per capita (V13) with negative magnitude (-0.513). Factor three measures Electricity generation (V2) with magnitude -0.887. In figure 3 the axes are given by the principal directions, in which the data varies. Factor one axis is the main direction, along which the data shows the greatest variation (57.44%), and factor 2 axis, orthogonal with factor one, gives the second most important direction (10.79%).

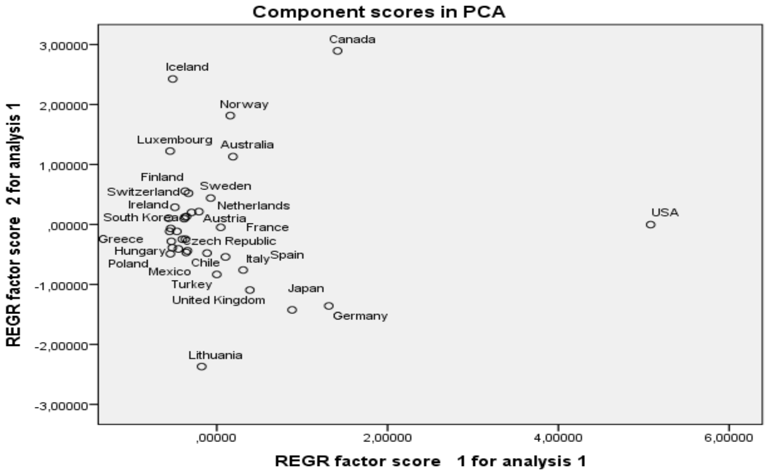
Figure 3. Correlation circle



Source: Authors

The correlation circle describes the relationships between all variables. Positively correlated variables are grouped together, meaning that in our case all 13 variables are positively correlated (Kassambara, 2017), a fact confirmed by the correlation matrix in figure 1. At the same time the correlation circle is related with the loading factors from table 4 and their impact on the first two factors. According to an article from Click Energy (Click Energy, 2020), among the 12 countries leading the way in renewable energy, from our set of OECD countries, Iceland is the top electricity producer from renewables. Iceland's energy comes almost 100% from renewable energy, especially geothermal and hydroelectric power plants. Sweden gave up the use of fossil fuels and invested more in energy power, solar power and smart grids (Haller, 2020). The most part of the energy UK produces comes from wind power rather than coal power plants, while Ireland follows the same (Raišienė et al., 2019) trend. Denmark produces almost 40% of its electricity from wind power and intends to entirely give up fossil fuel by 2050.17.3% of Canada's energy comes from renewables (Government of Canada, 2020), compared to OECD countries which have a share in renewables of 10.2% in their energy supply. On an international scale, US' renewable energy ranks third with 9% of the world production, while Canada ranks seventh with 7%. This explains the distinct position of US and Canada on the component score plot.

Figure 4. Component scores plot



Source: Authors

6. Conclusions

The present study applied PCA based on 13 variables and three factors explaining 76.098% of the total variance have been retained, the informational loss being of about 23.9%. The results revealed that factor 1 accounting for 57.44% of the total variance is negatively correlated with most of the renewable energy indicators. Therefore, we can say that factor 1 comprises renewable energy sources: traditional biofuels, hydropower, solar, wind and other renewables, as well as energy imports, exports, capacity and generation. The component score plot revealed that Canada, USA and Iceland are outliers in this representation.

Future research should be based on time-series analysis, e.g. moving average, autoregressive moving average, exponential smoothing, etc. A multivariate approach would be recommended based on sufficient data. The results of our research show that renewable energy sources have a positive and direct influence on economic and social indicators integrated and processed with PCA. Economic implications increase electricity production and lower production costs, while social implications increase the quality of life and environmental protection.

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