Article

The Impact of Renewable Electricity Output on Sustainability in the Context of Circular Economy: A Global Perspective

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Abstract: In this article we investigate the impact of "*Renewable Electricity Output*" on green economy in the context of circular economy for 193 countries in the period 2011-2020. We use data from World Bank ESG framework. We perform Panel Data with Fixed Effects, Panel Data with Random Effects, WLS, and Pooled OLS. Our results show that Renewable Electricity Output is positively associated, among others, to "*Adjusted Savings-Net Forest Depletion*" and "*Renewable Energy Consumption*" and negatively associated, among others, to "*CO2 Emission*" and "*Cooling Degree Days*". Furthermore, we perform a cluster analysis implementing the k-Means algorithm optimized with the Elbow Method and we find the presence of 4 clusters. Finally, we confront seven different machine learning algorithms to predict the future level of "*Renewable Electricity Output*". Our results show that Linear Regression is the best algorithm and that the future value of renewable electricity output is predicted to growth on average at a rate of 0.83% for the selected countries.

JEL CODE: Q5, Q50, Q51, Q52, Q53.

Keywords: environmental economics; general; valuation of environmental effects; pollution control adoption and costs; recycling

1. Introduction-Research Question

In the following article we analyzed the value of renewable energy in the context of the circular economy considering the need to create greater sustainability and resilience of global energy systems. The dataset used for the analysis is the "*Environmental, Social and Governance-ESG"* of the World Bank [1]. However, as part of the large dataset, the variables relating to energy production in 193 countries for the period 2011-2020 were mainly analyzed. The circular economy paradigm requires attention to all phases of production and consumption in all countries globally. However, notoriously, the possibility of triggering economic growth processes, economic development, and the achievement of potential productivity, in all countries, requires energy consumption. In fact, the consumption of energy worldwide always tends to grow despite crises and regardless of the application of technological innovation to energy production methods.

However, the need to grow in income production could push countries to use highly polluting energy sources such as non -renewable carbon -based energy sources. In this sense, the question of the energy sustainability of economic growth becomes an objective of economic policy both nationally and internationally. In fact, governments are found in the need to guarantee on the one hand growing and prosperity to their nation, and on the other hand they must respect the international cooperation agreements that are oriented to the reduction of CO2 emissions to reduce overheating globally. In this sense, the so-called Paris Agreements [2] and the COP27 [3] recently held in Egypt, try to impose very ambitions of environmental policy to countries to combat the climate change.

One of the methods that can allow to increase the propensity to the circular economy in the context of the sustainability of economic growth processes is renewable energy. In

 doi:10.20944/preprints202212.0193.v1

fact, renewable energy tends to be positively associated with the reduction of CO2 emissions and the reduction of temperature. Furthermore, since the renewable energy production methodologies require the use of a sort of production decentralization also derives the possibility of offering energy at reasonable prices even in regional, local and rural areas that in the past would not have had the opportunity to participate in the energy production.

However, the use of renewable energy is certainly not free from criticism or economic and technological limitations. In fact, as reported in paragraph 2 relating to the analysis of literature, there are empirical studies that have shown how economic growth is more compatible with the use of non -renewable energy sources rather than renewable energy sources. This dynamic can be understood because for a country it is certainly easier and faster to grow in GDP through pollution especially if it is a developing country that intends to fit into the ranks of medium and high-income countries.

However, these methodologies of economic growth are very risky as they generate pollution and relevant negative externalities at the environmental level that weigh both on the national population and on the global energy balance. It therefore derives the need to find new solutions, new economic policies, which keep together economic growth, respect for the environment, need to grow energy consumption, with the reduction of CO2 emissions. One of the methodologies to achieve the compatibility between sustainability of circular economic and economic growth consists in the growth of renewable energy production. Renewable energy can also have further positive effects at the country level by changing the mentality not only of producers as well as consumers relating to the impact of productive and consumption choices on the environment. This change of mentality and public sensitivity can have an impact especially in developing countries and in new industrialization countries to facilitate an overall passage to the circular economy, operating as a cultural and value reform supported by the positive experience relating to production and renewable energy consumption. Although there are certainly models of economic growth that have hypothesized the total passage also of medium-high income economies to the circular economy through the exclusive use of renewable energy, it is known that renewable energy still has limitations in the ability to be a useful tool to support, alone, the productivity of an industrialized country.

However, it is very probable that new technologies that can effectively use the forces of nature to generate energies without emission of CO2, in a compatible way for the environment are very probable through the investment of research and development. R&D can promote new technology to support the renewable energy production for cities, manufacturing industry, as well as means of transport [4].

The development of renewable energy therefore becomes the essential element to guarantee the sustainability of the economic growth of countries, and to allow a full transition to the circular economy.

The article continues as follows: in the second paragraph a brief analysis of literature is presented which analyzes the relationship between the use of renewable energy and sustainability of economic growth, in the third paragraph an econometric model is presented for the esteem of the determinants of the production of renewable energy, in the fourth paragraph the clusterization with k-Means algorithm optimized with the Elbow Method to investigate the presence of groupings among the 193 countries analyzed in terms of renewable energy production, in the fifth paragraph is presented with a prediction with algorithms of Machine Learning-ML to identify a path of possible development of renewable energy production, the sixth paragraph concludes.

2. Literature Review

A brief analysis of the literature is presented below which above all takes into consideration the relationship between the production of renewable energy and the sustainability of economic growth processes.

[5] verify the existence of a positive relationship between the value of financial inclusion, globalization, the reduction of carbon dioxide emissions and the presence of energy from renewable sources. [6] establishes a positive relationship between economic development and renewable electricity consumption in the Baltic region using data for the period 1992-2011. [7] analyzes the presence of a causal link between renewable energy, non-renewable energy, and economic growth for 26 OECD countries. The author concludes by arguing that economic growth policies should encourage renewable energy to facilitate economic growth and increase energy independence at the country level. [8] consider the relationship between renewable energy production and gross domestic product in 36 OECD countries over the period 2001-2015. The authors verify the existence of a negative relationship between GDP growth and an increase in the production of renewable energy. This report suggests that economic growth and development of renewables do not necessarily go hand in hand, especially in countries with medium-high per capita income.

[9] investigate the existing relationships between CO2 emissions, renewable electricity consumption, non -renewable electricity consumption, and economic growth in Algeria in the period between 1980 and 2012. The results show that in the long run the economic growth and the consumption of energy does not renewable have a negative effect on the quality of the environment, while the use of renewable energy positively impacts the quality of the environment. Energy consumption is produced by economic growth. However, to improve the environmental condition in Algeria it is necessary to invest in renewable energy by generating positive effects also in terms of reducing CO2 emissions. [10] analyze the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, and CO2 emissions in Mediterranean countries in the period between 1980 and 2014. The authors verify the presence of a negative relationship between the use of renewable energy, CO2 emissions and economic growth. It follows that if on the one hand the use of renewable energy can reduce CO2 emissions, on the other hand it is not certain that it is compatible with a program of economic growth in the short term.

[11] analyze the relationship between renewable energy production, GDP growth and CO2 emissions in Pakistan. The results show that in the long run CO2 emissions, renewable energy production and GDP growth increase together. The authors suggest that economic policies be applied to increase the production of renewable electricity and reduce CO2 emissions in Pakistan. [12] consider the positive impact that the ecological transition and the switch to a fully renewable energy production system could have on the Dutch economy. The authors estimate that the transition to renewable energy could create 50,000 new jobs by 2030 and increase gross domestic product by 1%. [13] confirm the presence of a positive relationship between both renewable and non-renewable energy production in terms of economic growth for 174 countries between 1980 and 2012.

[14] underline the need to strengthen and facilitate the transition to fully sustainable and renewable energy-based production energy systems globally. The energy transition to a system completely free from carbon sources is considered as a necessary objective to respect the limits of growth of global temperatures established in international agreements and treaties. [15] analyzes the positive relationship between the production of renewable energy and the reduction of CO2 emissions in South America over the period 1980-2010. [16] verify the presence of a positive relationship between renewable energy production, CO2 reduction and gross domestic product growth in a panel of 84 countries between 1991 and 2012. [17] consider the perverse effects that the apolitical economic incentive for renewable energy installations has had on households in Germany. In fact, federal government subsidies for renewable energy production have pushed up prices. Poor households have been faced with higher energy prices. The authors suggest solutions to combine the growth in the price of renewable energy with the need to offer subsidies to households.

[18] considers the impact of the energy transition to renewable energy from a regional perspective. The method of investigation is bibliographic. The analysis starts from the idea

that since renewable energies have a degree of reduced energy density, a significant change of the areas in which renewable energy is produced above all at a regional, local, and rural level derives. Effects in terms of employment, supply chains and value are thus detectable which are achieved at regional and local level. [19] analyze the impact of renewable energy in terms of economic growth in 38 countries in the period between 1990 and 2018. The results show the presence of a positive relationship between renewable energy production and economic growth. The authors suggest implementing actions at international, governmental, and intergovernmental level to increase the production and consumption of renewable energy.

As evident, the analysis of literature tends to confirm the presence of a positive relationship between the growth of renewable energy production and reduction of CO2 emissions. However, the relationship between the growth of the production of renewable energy and growth of the gross domestic product is ambiguous, at least in the long run. It should be considered that almost all the articles analyzed apply analytical methodologies aimed at investigating the presence of causal relationships between the variables. Furthermore, the ambiguity of the metric results about the relationship between renewable energy production and economic growth rate depends on the fact that the analyzed data fails to incorporate the implementation of the new economic policies arranged internationally to combat the climate Change is likely to be incorrectly and reduce CO2 emissions.

3. The Econometric Model to Estimate the Determinants of Renewable Electricity Output

An econometric analysis is then carried out for the estimation of the determinants that affect the facilitation of the production of renewable energy. The data used refer to 193 countries worldwide in a 10-year period between 2011 and 2020. The data were analyzed with the following econometric techniques, namely: Panel Data with Fixed Effects, Panel Data with Random Effects, Pooled OLS, WLS.

The following equation was explicitly estimated:

$$\begin{aligned}
\boldsymbol{RenewableElectricityOutput_{it}} &= \boldsymbol{a_1} + \boldsymbol{b_1}(\boldsymbol{AccessToElectricity})_{it} \\
&+ \boldsymbol{b_2}(\boldsymbol{AdjustedSavingNaturalResourcesDepletion})_{it} \\
&+ \boldsymbol{b_3}(\boldsymbol{AdjustedSavingsNetForestDepletion})_{it} \\
&+ \boldsymbol{b_4}(\boldsymbol{AgriculturalLand})_{it} + \boldsymbol{b_5}(\boldsymbol{AgricultureForestryAndFishing})_{it} \\
&+ \boldsymbol{b_6}(\boldsymbol{CO2Emissions})_{it} + \boldsymbol{b_7}(\boldsymbol{CoolingDegreeDays})_{it} \\
&+ \boldsymbol{b_8}(\boldsymbol{ElectricityProductionFromCoalSources})_{it} \\
&+ \boldsymbol{b_9}(\boldsymbol{EnergyUse})_{it} + \boldsymbol{b_{10}}(\boldsymbol{ForestArea})_{it} \\
&+ \boldsymbol{b_{11}}(\boldsymbol{FossilFuelEnergyConsumption})_{it} \\
&+ \boldsymbol{b_{12}}(\boldsymbol{PM2.5AirPollution})_{it} \\
&+ \boldsymbol{b_{13}}(\boldsymbol{RenewableEnergyConsumption})_{it}
\end{aligned}$$

Where $\boldsymbol{i = 193}$ and $\boldsymbol{t = 10}$.

Based on the analysis it appears that the value of Renewable Electricity Output is negatively associated with:

- *Cooling Degree Days:* is a variable that considers the quantification of the demand for energy necessary to cool buildings. From a metric point of view, consider the number of grades of the average temperature above 18°C. There is a negative relationship between the value of renewable energy production and the Cooling Degree Days value. In countries where there is greater production of renewable electricity there is also less demand for energy necessary to cool buildings. This relationship could certainly be true for some countries that are particularly efficient from an energy point of view in northern Europe where the number of days having temperature above 18 degrees Celsius tends to be lower. However, this report, regardless of geographical considerations, can also indicate the positive contribution that the presence of renewable energy production sources offers against global warming.

- *CO2 Emissions:* considers carbon dioxide emissions, i.e. those deriving from the combustion of fossil fuels and the production of cement. They include carbon dioxide produced during the burning of solid, liquid, and gaseous fuels and gas flaring. There is a negative relationship between the production of carbon dioxide and the production of energy from renewable sources. This negative relationship allows us to support the possibility of combating global warming through the efficient use of renewable sources. At present, renewable energies certainly cannot fully replace the value of energy production from traditional sources. However, the possibility of reducing CO2 emissions allows energy economic policy to effectively use renewable energy as a tool to combat emissions and reduce pollution especially in urban areas, also having positive impacts in terms of public health for the population.
- *Adjusted Savings: Natural Resources Depletion (% of GNI);* is the sum of net forest depletion, energy depletion, and mineral depletion. Net forest depletion is the unit resource rent multiplied by the excess harvest of timber more than natural growth. Energy depletion is the ratio of the value of the stock of energy resources to the remaining life of the reserve. It covers coal, crude oil and natural gas. Mineral depletion is the ratio of the stock value of mineral resources to the remaining life of the reserve. There is therefore a negative relationship between the value of depletion of natural resources and the value of renewable energy production. This report indicates that by effectively increasing the production of renewable energy it is possible to reduce the consumption of natural resources and thus safeguard the environment.
- *Agriculture, Forestry, And Fishing, Value Aided (% of GDP):* is a measure of the impact of agriculture, silviculture, and fishing in terms of GDP. There is a negative relationship between the value of the percentage of GDP produced by the primary sector and the value of the growth of renewable energy production. This relationship can be understood considering that for example the production of renewable energy is often placed in a zero-sum game with agriculture. For example, solar energy often occupies the same spaces and is built on the same land that could be dedicated to agriculture. However, this is not only the motivation of this negative relationship. There is also another one that is worth above all for the countries of northern Europe and for medium-high income countries. In fact, generally medium-high income countries tend to have a value of agriculture as a percentage of very reduced GDP, and generally less than 4% if not even 3%.
- *Electricity Production from Coal Sources (% of Total):* is the share of electricity produced using coal. Coal means all coal and lignite, both primary fuels including hard coal and lignite-lignite, and derivative fuels including proprietary fuels, coke oven coke, gas coke, coke oven gas and blast furnace gas. Peat is also included in this category. There is a negative relationship between the value of electricity generation from coal and the value of generation from renewable energy. This relationship allows us to identify a zero-sum game between the production of energy from renewable sources and the production of energy from coal. However, it is not possible to imagine a complete substitution of renewables with coal, at least considering the current conditions of the technology applied to renewable sources. However, the report certainly indicates that investing in renewables can make it possible, within certain limits, to reduce the production of energy from coal.
- *Agricultural Land (% of Land Area):* represents the amount of land devoted to agriculture as a percentage of available land in each country. There is a negative relationship between the value of land available in each country for cultivation and the value of renewable energy production. This relationship tends to reinforce the hypothesis of the presence of a zero-sum game between agriculture and the value of renewables. The motivation lies in the fact that obviously where the renewable energy plants are installed it is not possible to proceed with the exercise of land cultivation. However, it must also be considered that especially for the countries of Northern Europe, obviously, the percentage of land dedicated to agriculture tends to be small, while the

areas destined for wind, geothermal and solar plants can be very large and productive.

In addition, the value of "*Renewable Electricity Output*" is positively associated with:

- *Energy Use (Kg of Oil equivalent for Capita):* considers energy consumption as the use of primary energy before transformation into other end-use fuels, equal to domestic production plus imports and changes in stocks, minus exports and fuels supplied to ships and aircraft engaged in international transport. There is a positive relationship between energy consumption and investment in renewable energies. Evidently renewable energy contributes to the production of energy at the local level and therefore generates an increase in available energy and related consumption. It is also true that energy consumption tends to be ever increasing in almost all countries. However, certainly having greater quantities of energy available certainly also allows us to sustain greater consumption. Furthermore, renewable energy is often produced in rural locations and therefore, also at the distribution level, it allows for an increase in consumption capacity even in territories that otherwise would be almost isolated.
- *Access to Electricity (% of population);* is a variable that considers access to electricity as the percentage of the population that has access to electricity. Electrification data is collected from industry, national surveys, and international sources. There is a positive relationship between the value of access to electricity and investment in renewable energy production. Obviously, the growth in energy production makes it possible, especially in rural areas, for access to electricity to people who were previously excluded from it. This is especially true for countries that have low per capita incomes and are in Africa or South Asia. Obviously, the possibility of producing energy even in the vicinity of rural, peripheral areas further increases the inclusiveness of renewable sources. Renewable energies therefore become a tool for reducing social and economic inequality, allowing the population of many countries to access the use of electricity.
- *Forest Area (% of Land Area):* it is a variable that considers the forest area or the land under natural woods or trees planted with at least 5 meters in situ, whether productive or not, and excludes woods in agricultural production systems and trees in parks and urban gardens. There is a positive relationship between the value of forest area and the investment in renewable energy production at the country level. This relationship is since the installation of renewable energy production stations generally does not take place in forest areas. In fact, renewable energies do not use any of the products that directly or indirectly can be obtained from the exploitation of forests as an input. For this reason, it is possible to develop renewable energy and at the same time make sure that the forest area also grows thanks to the cultural effects induced by renewables.
- *PM2.5 Air Pollution, Mean Annual Exposure (Micrograms for Cubic Meter):* considers exposure to environmental PM2.5 pollution is defined as the average level of exposure of a nation's population to concentrations of airborne particles measuring less than 2.5 microns in aerodynamic diameter, which are capable of penetrating deeply into the respiratory tract and cause serious damage to health. There is a positive relationship between the value of renewable energies and the growth of pollution due to the presence of PM2.5. This relationship may be since the presence of renewable energy sources by itself does not automatically eliminate other polluting sources of energy production or some methods of energy production that generate PM2.5 as in the case of fossil fuel-powered transport. It follows that especially in countries characterized by the presence of densely populated urban areas, there can be a simultaneous growth in investment in the production of renewable energy and a growth in pollution from PM2.5.
- *Fossil Fuel Energy Consumption (% of Total);* represents the energy consumption from fossil fuels as a % of the total energy consumption. There is a positive relationship

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between the value of investment growth in renewable energies and the value of energy consumption from fossil fuels. This motivation is since in general the countries that have access to the production of renewable energy, even if they are countries with a medium-low per capita income, can experience forms of economic growth. And this economic growth can, for example, be accompanied by the diffusion of means of transport such as cars, motorcycles, buses, and therefore by an increase in the use of fossil fuels. In fact, the process of economic development that leads a country to grow in the level of income is extremely expensive from an energy point of view and therefore also requires the use of fossil energy sources both for the production purposes of the industries and for the consumption purposes of the families.

- *Renewable Energy Consumption (% of Total Final Energy Consumption):* is a variable that considers the consumption of renewable energy in the total final energy consumption. Obviously, there is a positive relationship between the value of renewable energy production and the consumption of renewable energy at the country level. This relationship represents a kind of tautology. In fact, if there is greater production of renewable energy, and therefore the share of renewable energy out of the total energy produced increases, as well as the share of renewable energy consumed out of the total energy consumed. Furthermore, it must be considered that this relationship is practically immediate for those renewable energy installations which are connected to domestic users, and which therefore support the capacity of families to consume energy. However, this relationship has limitations. For example, to meet the demands of cities and energy-intensive industries it can be very difficult to act with the supply of renewable energy. Therefore, it is probable that this relationship, although verified at the country level, may then encounter limitations if analyzed at the local or regional level.
- *Adjusted Savings: Net Forest Depletion (% of GNI):* is calculated as the product of unit resource rents and the excess log harvest over natural growth. There is a relationship between the value of the growth of investment in renewable energy and the growth of net impoverishment. This relationship may appear counterfactual, however it can be better understood because most of the countries that have invested heavily in renewable energies are also developing countries in which the primary sector is very relevant. And since the forestry activity is a primary type of extractive activity, it is probable that, at least for most middle-low-income countries, there is a positive convergence between net impoverishment and the growth of renewables. However, this relationship tends to change once countries reach the upper-middle per capita income level due to the reduction in the relative contribution of the primary sector including timber harvesting.

Econometric Models to Estimate the Value of Renewable Electricity Output										
		Fixed Effects		**Random Effects**		**Pooled OLS**		**WLS**		
		Coefficient	*p-Value*	*Coefficient*	*p-Value*	*Coefficient*	*p-Value*	*Coefficient*	*p-Value*	*Average*
	Coefficient	-4,8818	***	-4,7345	**	-4,3324	**	-4,3417	**	-4,5726
A2	*Access to electricity (% of population)*	0,0746	***	0,0754	***	0,0778	***	0,0777	***	0,0764
A3	*Adjusted savings: natural resources depletion (% of GNI)*	-0,1776	***	-0,1755	***	-0,1699	***	-0,1623	**	-0,1713
A4	*Adjusted savings: net forest depletion (% of GNI)*	1,0051	***	1,0117	***	1,0226	***	1,0134	***	1,0132
A5	*Agricultural land (% of land area)*	-0,0637	**	-0,0663	**	-0,0742	**	-0,0753	***	-0,0699
A6	*Agriculture, forestry, and fishing, value added (% of GDP)*	-0,1629	**	-0,1612	**	-0,1561	**	-0,1280	**	-0,1520
A11	*CO2 Emissions (metric tons per capita)*	-0,9580	***	-0,9370	***	-0,8780	***	-0,7845	***	-0,8894
A13	*Cooling Degree Days (projected change in number of degree Celsius)*	-7,1791	*	-7,8559	**	-9,7376	***	-8,7400	**	-8,3781
A16	*Electricity production from coal sources (% of total)*	-0,0869	**	-0,0906	**	-0,1004	***	-0,0745	**	-0,0881
A19	*Energy use (kg of oil equivalent per capita)*	0,0018	***	0,0017	***	0,0016	***	0,0013	***	0,0016
A22	*Forest area (% of land area)*	0,0945	***	0,0890	***	0,0735	***	0,0595	**	0,0792
A23	*Fossil fuel energy consumption (% of total)*	0,2148	***	0,2173	***	0,2239	***	0,2176	***	0,2184
A46	*PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)*	0,0868	**	0,0878	***	0,0914	***	0,0751	**	0,0853
A57	*Renewable energy consumption (% of total final energy consumption)*	0,4902	***	0,4881	***	0,4831	***	0,4849	***	0,4866

4. Clusterization with the k-Means Algorithm Optimized with the Elbow Method

In the following analysis a method is applied using the k-Means algorithm optimized with the Elbow Method. The application of a method of clusterization is necessary in a database consisting of 193 countries characterized by an enormous heterogeneity from an economic, social, institutional, and geographical point of view. In this way, clusterization allows the presence of groupings that can be due to a composite set of environmental economic policy choices that put together economic, geographical, financial, and technological elements. Generally, the Silhouette coefficient is used to optimize the K-means algorithm. However, due to the excessive polarization of the data, the use of the silhouette coefficient appeared excessively simplifying, manifestation of the existence of only two Clusters in a context of 193 countries. This analysis initially attempted would have simply

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represented a contrast between two blocks of countries, namely rich countries and poor countries. To grasp the greatest heterogeneity in the dataset, it was chosen to use the Elbow method that highlights four clusters. Specifically, the following clusters were identified, namely:

- *Cluster 1:* Angola, Belize, Cambodia, Canada, Congo Rep., Croatia, Denmark, Ecuador, El Salvador, Eswatini, Fiji, Gabon, Ghana, Guatemala, Guinea, Honduras, Latvia, Madagascar, Mali, Montenegro, Myanmar, Nicaragua, Panama, Peru, Portugal, Rwanda, Sierra Leone, Sri Lanka, Suriname, Sweden, Switzerland, Venezuela, Vietnam, Zimbabwe;
- *Cluster 2:* Algeria, Antigua and Barbuda, Australia, Azerbaijan, Bahamas, Bahrain. Bangladesh, Barbados, Belarus, Benin, Botswana, Brunei Darussalam, Bulgaria, Burkina Faso, Chad, Comoros, Cuba, Cyprus, Czech Republic, Djibouti, Dominican Republic, Egypt, Eritrea, Estonia, Finland, Gambia, Grenada, Guinea-Bissau, Guyana, Haiti, Hungary, Indonesia, Iran, Iraq, Israel, Jamaica, Japan, Jordan, Kazakhstan, Kiribati, Korea Rep., Kuwait, Lebanon, Liberia, Libya, Malaysia, Maldives, Malta, Marshall Islands, Mauritania, Micronesia, Moldova, Monaco, Mongolia, Morocco, Nauru, Netherlands, Niger, Oman, Palau, Poland, Qatar, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Seychelles, Singapore, Solomon Islands, Somalia, South Africa, South Sudan, St. Kittis and Nevis, St. Lucia, Syrian Arab Republic, Thailand, Timor-Leste, Tonga, Trinidad and Tobago, Tunisia, Turkmenistan, Tuvalu, Ukraine, United Arab Emirates, United States, Yemen Rep;
- *Cluster 3:* Afghanistan, Albania, Andorra, Austria, Bhutan, Brazil, Burundi, Cameroon, Central African Republic, Colombia, Congo Dem. Rep., Ethiopia, Georgia, Iceland, Kenya, Kyrgyz Republic, Lao PDR, Lesotho, Liechtenstein, Malawi, Mozambique, Namibia, Nepal, New Zealand, Norway, Paraguay, Sudan, Tajikistan, Togo, Uganda, Uruguay, Zambia;
- *Cluster 4:* Argentina, Armenia, Belgium, Bolivia, Bosnia and Herzegovina, Cabo Verde, Chile, China, Cote d'Ivoire, Dominica, Equatorial Guinea, France, Germany, Greece, India, Ireland, Italy, Korea, Dem. People's Rep., Lithuania, Luxembourg, Mauritius, Mexico, Nigeria, North Macedonia, Pakistan, Papua New Guinea, Philippines, Romania, Russian Federation, Samoa, Serbia, Slovak Republic, Slovenia, Spain, St. Vincent and the Grenadines, Tanzania, Turkey, United Kingdom, Uzbekistan, Vanuatu.

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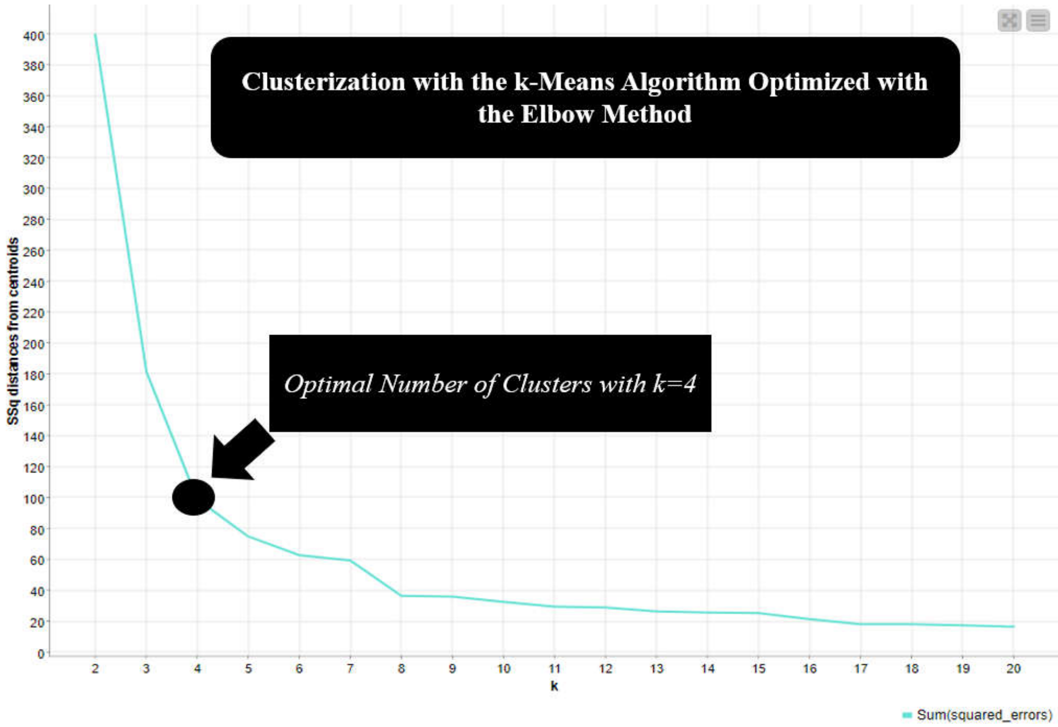

Considering the value of the median of the clusters, it results that Cluster 3-C3 is equal to an amount of 91.63, while Cluster-C1 is equal to an amount of 54.64 units, Cluster-C4 is equal to an amount of 25.41 units and Cluster 2-C2 equal to an amount of 1.47. The following ordering of the clusters therefore derives: C3>C1>C4>C2. From a geographical point of view, we can see that it is above all the countries with low per capita incomes that have the greatest percentage of electricity production from renewable sources. However, this condition can be better explained by considering that countries that have low per capita incomes are in the following situation:.

- have probably not invested sufficiently in traditional forms of energy production due to lack of infrastructure;
- being African and Asian countries, they are in the climatic conditions to optimize the advantages of renewable energies.

However, there are of course exceptions. For example, in Cluster 3-C3 which is the one that has the greatest value in terms of presence of renewable energy production, there are also Liechtenstein, Norway, Austria, New Zealand, and Iceland. It is obviously a presence that needs to be explored. In the case of Austria, most of the renewable energy is produced by hydroelectricity, followed by solar, biomass, solar and geothermal. Also, in Norway the main source of energy is hydroelectricity, followed by solar and thermal energy. Finally, Iceland manages to produce geothermal and wind energy. However, we must consider that Austria, Norway, Iceland are small countries, and their energetic demand is smaller in respect to other more populous high-income countries.

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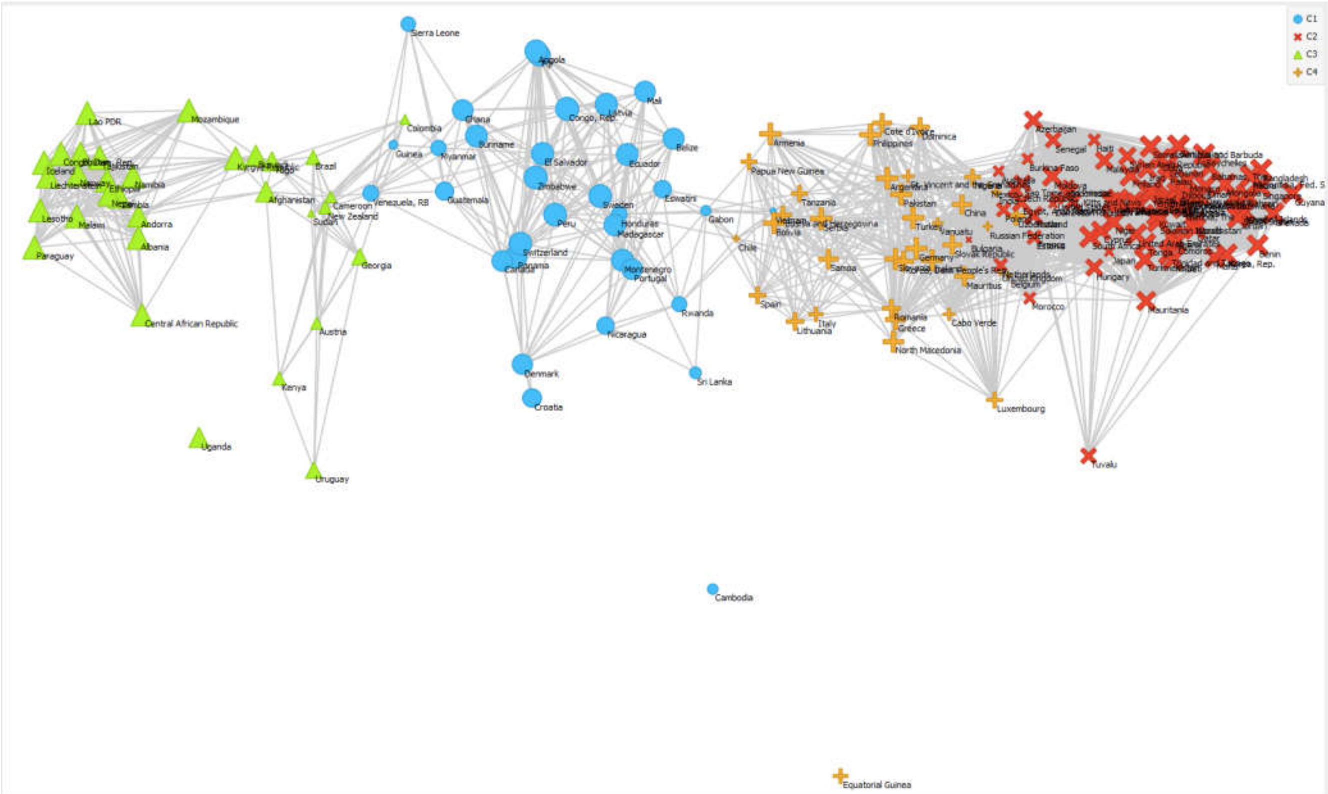

5. Machine Learning and Predictions

Below is a comparison between seven different Machine Learning algorithms for the prediction of the future value of renewable energy production. The algorithms were evaluated based on their statistical capacity measured based on the maximization of the R-Squared and the minimization of the following statistical errors or: Mean Absolute Error-MAE, Mean Squared Error-MSE, Root Mean Squad Error-RMSE. The algorithms were trained with 70% of the data while the remaining 30% was used for the actual prediction. The following order of Machine Learning algorithms for predictive performance was therefore obtained or:

- Linear Regression with a payoff equal to 4;
- Polynomial Regression with a payoff equal to 7;
- Gradient Boosted Trees Regression with a payoff value of 11;
- Tree Regression Ensemble with a payoff value of 12;
- Simple Regression Tree with a payoff value of 17;
- ANN-Artificial Neural Network with a payoff value of 21;
- PNN-Probabilistic Neural Network with a value of 25.

Therefore, using the best performing algorithm or Linear Regression it is possible to predict the following values for the countries indicated, i.e.:

- Antigua and Barbuda with an increasing variation from an amount of 0.10 up to a value of 0.11 units or equal to 0.01 equivalent to 10.00%;

1. Armenia with a change of an amount of 28.20 units up to a value of 28.18 units or equal to a change of -0.02 units equal to -0.07%;

- Bahrain and Barbados which in 2020 recorded 0.00% of renewable energy production remain in their condition without further investing in the growth of energy produced through renewables;
- Belarus with a diminutive variation from an amount of 0.74 units up to a value of 0.72 units or a variation equal to -0.02 units equal to -3.303%;

- Botswana with a change of an amount of 0.04 units up to a value of 0.07 units or equal to a value of 0.03 units equal to a value of 64.33%;
- Brazil with a variation from an amount of 76.24 units up to a value of 76.21 units or equal to a variation of -0.03 units equal to a value of -0.04%;
- Brunei Darussalam with a variation from an amount of 0.05 units up to a value of 0.06 units or equal to a value of 0.01 units or equal to a variation equal to a value of 28.00%;
- Burkina Faso with a variation from an amount of 11.66 units up to a value of 11.65 units or equal to a value of -0.01 units equal to a value of -0.11%;
- Burundi with a value of 85.53 units up to a value of 85.40 units equal to a value of -0.13 units equal to a value of -0.15%;
- Cabo Verde with a variation from an amount of 18.48 units up to a value of 18.49 units or equal to a variation of 0.01 units equal to a value of 0.03%;
- China with a variation from an amount of 22.01 units up to a value of 22.99 units or equal to a variation of 0.98 units equal to an amount of 4.45%;
- Colombia with a variation from an amount of 72.98 units up to a value of 72.97 units or equal to a variation of -0.01 units equal to a variation of -0.01%;
- Comoros with zero variation and a value of renewable energy production equal to 0;
- Congo with a variation from an amount of 99.79 units up to a value of 99.76 units or equal to a value of -0.03 units equal to a value of -0.03%;
- Czech with a zero change in absolute value and a marginal change in percentage value equal to 0.02 for a total value of renewable energy produced equal to 10.69%;
- Dominica with a diminutive variation from an amount of 20.52 units up to a value of 20.49 units or equal to a variation of -0.03 units equal to a value of -0.16%;

2. Dominican Republic with a zero change in absolute value and an amount of renewable energy production equal to a value of 13.25%;

- El Salvador with an increasing variation from an amount of 59.34 units up to a value of 59.35 units or equal to a value of 0.01 units equal to a variation of 0.02%;
- Eritrea with a variation from an amount of 0.52 units up to a value of 5.53 units or equal to a variation of 5.01 units equal to an amount of 963.08%;
- Eswatini with a variation from an amount of 46.93 units up to a value of 46.95 units or equal to a variation of 0.02 units equal to an amount of 0.04%;
- Gabon with a variation from an amount of 42.93 units up to a value of 42.40 units or equal to an amount of -0.53 units in absolute value equivalent to -1.23%;
- Georgia with an increasing variation from an amount of 78.78 units up to a value of 78.79 units or equal to a value of 0.01 units equal to a value of 0.01%;
- Germany with a diminutive variation from an amount of 26.26 units up to a value of 26.25 units or equal to an amount of -0.01 units equal to an amount of -0.03%;
- Greece with a variation from an amount of 24.54 units up to a value of 24.56 units or equal to an amount of 0.02 units equal to a value of 0.08%;
- Haiti with a variation from an amount of 10.95 units up to a value of 10.96 units equal to an amount of 0.01 units equal to a value of 0.11%;
- Honduras with zero variation and an amount of renewable energy production equal to a value of 44.59 units;
- Italy with a variation from an amount of 37.99 units up to a value of 37.00 units or equal to a value of -0.99 units equal to a value of -2.61%;
- Kazakhstan with a variation from an amount of 0.14 units up to a value of 1.91 units equal to a value of 1.77 units equal to a value of 1267.14%;

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- South Korea with a diminutive variation from an amount of 1.68 units up to a value of 1.60 units or equal to a value of -0.09 units equivalent to -5.06%;
- Lao PDR with a diminutive variation from an amount of 94.33 units up to a value of 94.31 units equal to an amount of -0.02 units equal to a value of -0.02%;
- Lebanon with a variation from an amount of 3.78 units up to a value of 3.87 units equal to an amount of 0.09 units equal to a value of 2.38%;
- Luxembourg with a variation from an amount of 23.48 units up to a value of 23.50 units or equal to an amount of 0.02 units equal to a value of 0.10%;
- Malaysia with a variation from an amount of 9.11 units up to a value of 9.24 units or equal to an amount of 0.13 units equal to a value of 1.43%;
- Malta with an increasing variation from an amount of 4.35 units up to a value of 4.52 units or equal to an amount of 0.17 units equal to a value of 3.91%;
- Marshall Islands with a variation from an amount of 0.23 units up to a value of 2.23 units or equal to a value of 2.00 units equal to an amount of 868.70%;
- Mauritania with a variation from an amount of 7.47 units up to a value of 7.02 units or equal to a variation of -0.45 units equal to an amount of -6.02%;
- Mexico with a variation from 15.25 units up to a value of 15.23 units or equal to a variation of -0.02 units equal to -0.13%;
- Moldova with a variation from an amount of 5.78 units up to a value of 5.77 units or equal to a value of -0.01 units equal to -0.17%;
- Monaco with zero change in renewable energy production;
- Niger with an increasing variation from an amount of 0.66 units up to a value of 6.66 units or equal to a value of 6.00 units equal to a value of 908.79%;
- Nigeria with zero absolute variation and an amount of renewable energy production equal to an amount of 18.55;
- Peru with a variation from an amount of 53.46 units up to a value of 53.45 units or equal to a value of -0.01 units equal to a value of -0.02%;
- Poland with a variation from an amount of 12.11 units up to a value of 12.09 units or equal to a variation of -0.02 units equal to an amount of -0.17%;
- Qatar with zero variation and an amount of renewable energy production equal to 0.00%;
- Russian Federation with a diminutive variation from an amount of 16.20 units up to a value of 16.19 units or equal to an amount of -0.01 units equal to a value of -0.06%;
- Rwanda with a variation from an amount of 48.18 units up to a value of 48.17 units or equal to a value of -0.01 units equal to -0.02%;
- Sao Tome and Principe with a variation from an amount of 9.71 units up to a value of 9.17 units or equal to a value of -0.54 units equal to a value of -5.56%;
- Seychelles with a variation from an amount of 1.79 units up to a value of 1.08 units or equal to a value of -0.71 units equal to an amount of -39.72%;
- Sierra Leone with a variation from an amount of 64.94 units up to a value of 64.89 units or equal to a value of -0.05 units or equal to a value of -0.08%;
- St. Kitts and Nevis with a variation from an amount of 4.23 units up to a value of 4.19 units equal to an amount of -0.04 units equal to a value of -0.95%;
- Timor-Leste and Trinidad and Tobago with zero variation and an absolute value of renewable energy production equal to an amount of 0.00 units;
- Tuvalu with a variation from an amount of 11.68 units up to a value of 11.66 units up to a value of -0.02 units equal to an amount of -0.14%;
- Uganda with a variation from an amount of 90.23 units up to a value of 90.24 units or equal to an amount of 0.01 units equal to a value of 0.01%;

- United Kingdom with zero variation and an amount of renewable energy production equal to an amount of 19.16%;
- Uruguay with a variation from an amount of 83.14 units up to a value of 83.10 units or equal to a value of -0.04 units equal to a value of -0.05%;
- Zimbabwe with a variation from an amount of 54.88 units up to a value of 54.84 units or equal to a value of -0.04 units equal to a value of -0.07%.

Predictions with the Best Predictor									
Country	**2020**	**Prediction**	**Abs Var**	**%**	**Country**	**2020**	**Prediction**	**Abs Var**	**%**
Antigua and Barbuda	0,1	0,11	0,01	10	*Korea, Rep.*	1,68	1,6	-0,09	-5,06
Armenia	28,2	28,18	-0,02	-0,07	*Lao PDR*	94,33	94,31	-0,02	-0,02
Bahrain	0	0	0	0	*Lebanon*	3,78	3,87	0,09	2,38
Barbados	0	0	0	0	*Luxembourg*	23,48	23,5	0,02	0,1
Belarus	0,74	0,72	-0,02	-3,03	*Malaysia*	9,11	9,24	0,13	1,43
Botswana	0,04	0,07	0,03	64,33	*Malta*	4,35	4,52	0,17	3,91
Brazil	76,24	76,21	-0,03	-0,04	*Marshall Islands*	0,23	2,23	2	868,7
Brunei Darussalam	0,05	0,06	0,01	28	*Mauritania*	7,47	7,02	-0,45	-6,02
Burkina Faso	11,66	11,65	-0,01	-0,11	*Mexico*	15,25	15,23	-0,02	-0,13
Burundi	85,53	85,4	-0,13	-0,15	*Moldova*	5,78	5,77	-0,01	-0,17
Cabo Verde	18,48	18,49	0	0,03	*Monaco*	0	0	0	0
China	22,01	22,99	0,98	4,45	*Niger*	0,66	6,66	6	908,79
Colombia	72,98	72,97	-0,01	-0,01	*Nigeria*	18,55	18,55	0	-0,01
Comoros	0	0	0	0	*Peru*	53,46	53,45	-0,01	-0,02
Congo, Dem. Rep.	99,79	99,76	-0,03	-0,03	*Poland*	12,11	12,09	-0,02	-0,17
Czech Republic	10,69	10,69	0	0,02	*Qatar*	0	0	0	0
Dominica	20,52	20,49	-0,03	-0,16	*Russian Federation*	16,2	16,19	-0,01	-0,06
Dominican Republic	13,25	13,25	0	-0,02	*Rwanda*	48,18	48,17	-0,01	-0,02
El Salvador	59,34	59,35	0,01	0,02	*Sao Tome and Principe*	9,71	9,17	-0,54	-5,56
Eritrea	0,52	5,53	5,01	963,08	*Seychelles*	1,79	1,08	-0,71	-39,72
Eswatini	46,93	46,95	0,02	0,04	*Sierra Leone*	64,94	64,89	-0,05	-0,08
Gabon	42,93	42,4	-0,53	-1,23	*St. Kitts and Nevis*	4,23	4,19	-0,04	-0,95
Georgia	78,78	78,79	0,01	0,01	*Timor-Leste*	0	0	0	0
Germany	26,26	26,25	-0,01	-0,03	*Trinidad and Tobago*	0	0	0	0
Greece	24,54	24,56	0,02	0,08	*Tuvalu*	11,68	11,66	-0,02	-0,14
Haiti	10,95	10,96	0,01	0,11	*Uganda*	90,23	90,24	0,01	0,01

Honduras	44,59	44,59	0	0	*United Kingdom*	19,16	19,16	0	0
Italy	37,99	37	-0,99	-2,61	*Uruguay*	83,14	83,1	-0,04	-0,05
Kazakhstan	0,14	1,91	1,77	1267,14	*Zimbabwe*	54,88	54,84	-0,04	-0,07

Therefore, considering the average values, it appears that the value of energy production from renewable sources is expected to grow by an amount equal to 0.21 units or equal to a value of 0.83%. From a strictly geographical point of view, it is foreseen that there will be a growth of renewable energies above all in the African continent, in China and in Kazakhstan. It follows that it will certainly be precisely the countries with low per capita incomes that will increase the value of the production of renewable energy. However, it is very probable that investments in scientific and technological research could lead to a further growth in the production capacity of renewables such as to allow an increase in use even in countries with higher per capita incomes which are generally characterized by greater demand of energy.

6. Conclusions

The circular economy is an economic policy landing that allows you to completely modify the production and consumption models both in developed countries and in developing countries. However, to make sure that the application of the circular economy is compatible with economic growth, it is also necessary to act in determining the energy production methods. In fact, since economic growth is very expensive in energy terms it is necessary to draw new energy production models that are sustainable. In this sense, it is necessary to develop the production of renewable energies in the context of the circular economy to allow the sustainability of economic growth. Certainly, renewable energies are very useful for quickly reducing CO2 production, global overheating, and offering solutions for energy consumption especially in rural, local areas. However, there are limitations in the use of renewable energies that consist of the low energy intensity and in the variability of some natural phenomena that are the basis of the production of renewable energy. These limitations must be understood as temporary. In fact, it is very likely that the application of research and development and technological innovation to the production of renewable energy can generate new production methods that can also offer energy to cities and manufacturing industrial systems. In any case, even if the transition to a completely renewable energy system may appear very difficult, poorly effective, and very complex at present, there are still good reasons to increase the presence of renewable energy in the energy balance at the country level and at the level global. Not least, the cultural and value effect must be considered, which can mainly concern developing countries which, through the experience of the production and consumption of renewable energy, can acquire positive expectations about the possibility of a sustainable economic model oriented to circular economy.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Software: The authors have used the following software: Gretl for the econometric models, Orange for clusterization and network analysis, and KNIME for machine learning and predictions. They are all free version without licenses.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We are grateful to the teaching staff of the LUM University Giuseppe Degennaro and to the management of the LUM Enterprise s.r.l. for the constant inspiration to continue our scientific research work undeterred.

Conflicts of Interest: The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication.

References

[1] W. Bank, "ESG," World Bank, [Online]. Available: https://datatopics.worldbank.org/esg/. [Accessed 2022 12 11].

[2] UN, "Paris Agreements," [Online]. Available: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. [Accessed 2022 12 11].

[3] COP27, "COP27," [Online]. Available: https://cop27.eg/#/. [Accessed 2022 12 11].

[4] W. Nordhaus, The climate casino: Risk, uncertainty, and economics for a warming world, Yale: Yale University Press., 2013.

[5] L. Qin, S. Raheem, M. Murshed, X. Miao, Z. Khan and D. Kirikkaleli, "Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output," *Sustainable Development,* vol. 29, no. 6, pp. 1138-1154, 2021.

[6] F. Furuoka, "Renewable electricity consumption and economic development: New findings from the Baltic countries," *Renewable and Sustainable Energy Reviews,* vol. 71, pp. 450-463, 2017.

[7] M. Aydin, "Renewable and non-renewable electricity consumption–economic growth nexus: evidence from OECD countries," *Renewable energy,* vol. 136, pp. 599-606, 2019.

[8] L. H. Melnyk, H. Sommer, O. V. Kubatko, M. Rabe and S. M. Fedyna, "The economic and social drivers of renewable energy development in OECD countries," *Problems and Perspectives in Management,* vol. 18, no. 4, pp. 37-48, 2020.

[9] F. Bélaïd and M. Youssef, "Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria," *Energy policy,* vol. 102, pp. 277-287, 2017.

[10] F. Belaïd and M. H. Zrelli, "Renewable and non-renewable electricity consumption, environmental degradation and economic development: evidence from Mediterranean countries," *Energy Policy,* vol. 133, no. 110929, 2019.

[11] A. Rehman, A. Rauf, M. Ahmad, A. A. Chandio and Z. Deyuan, "The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: evidence from Pakistan," *Environmental Science and Pollution Research,* vol. 26, no. 21, pp. 21760-21773, 2019.

[12] T. Bulavskaya and F. Reynès, "Job creation and economic impact of renewable energy in the Netherlands," *Renewable Energy,* vol. 119, pp. 528-538, 2018.

[13] B. Atems and C. Hotaling, "The effect of renewable and nonrenewable electricity generation on economic growth," *Energy Policy,* vol. 112, pp. 111-118, 2018.

[14] D. Bogdanov, M. Ram, A. Aghahosseini, A. Gulagi, A. S. Oyewo, M. Child and C. Breyer, "Low-cost renewable electricity as the key driver of the global energy transition towards sustainability," *Energy,* vol. 227, no. 120467, 2021.

[15] H. A. Hdom, "Examining carbon dioxide emissions, fossil & renewable electricity generation and economic growth: Evidence from a panel of South American countries," *Renewable energy,* vol. 139, pp. 186-197, 2019.

[16] M. Bhattacharya, S. A. Churchill and S. R. Paramati, "The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions," *Renewable Energy,* vol. 111, pp. 157-167, 2017.

[17] C. Böhringer, F. Landis and M. A. T. Reanos, "Economic impacts of renewable energy production in Germany," *The Energy Journal,* vol. 38, 2017.

[18] S. Jenniches, "Assessing the regional economic impacts of renewable energy sources–A literature review," *Renewable and Sustainable Energy Reviews,* vol. 93, pp. 35-51, 2018.

[19] M. Shahbaz, C. Raghutla, K. R. Chittedi, Z. Jiao and X. V. Vo, "The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index," *Energy*, no. 118162, p. 207, 2020.

Appendix

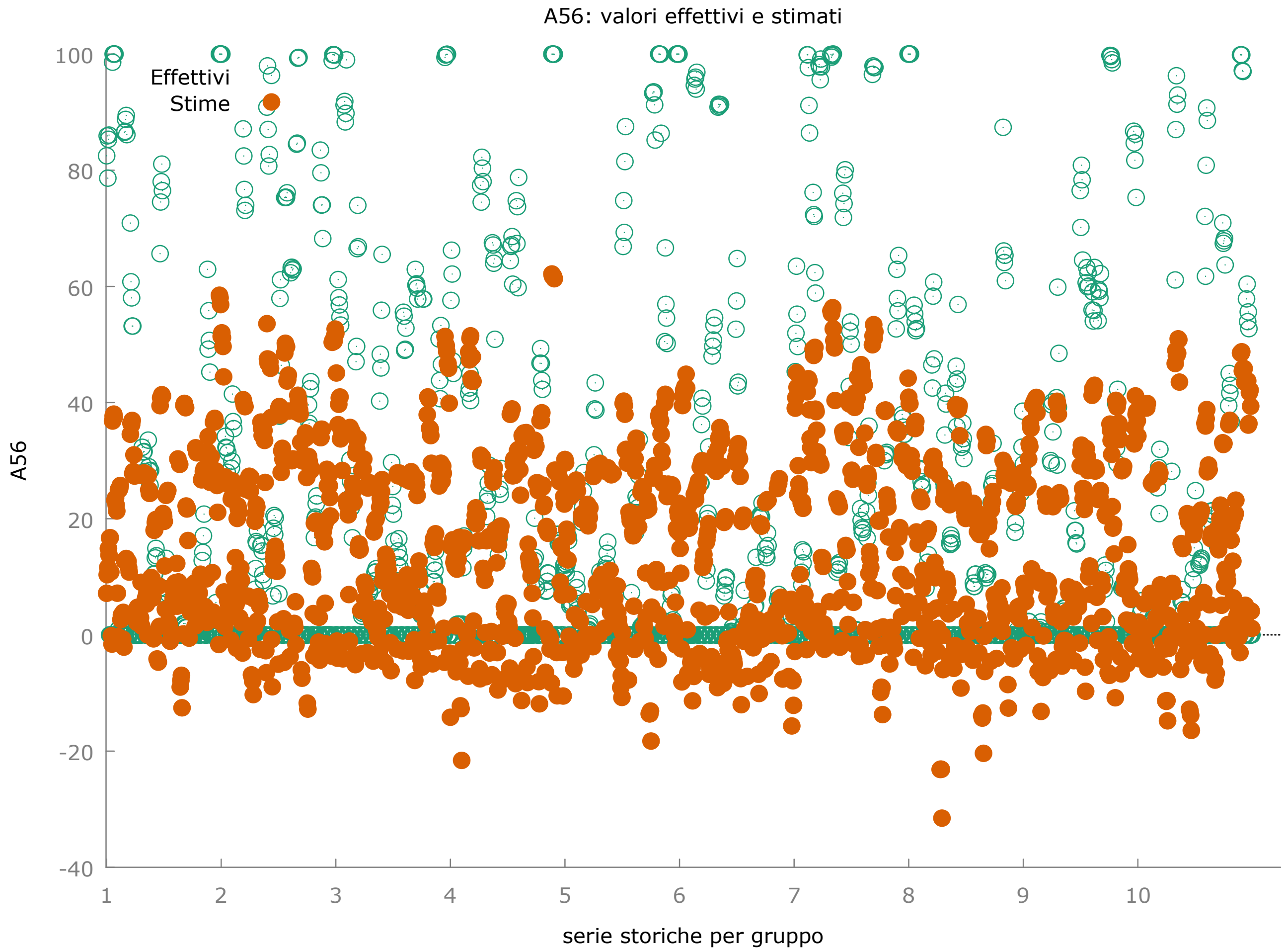
Modello 10: Effetti fissi, usando 1930 osservazioni
Incluse 10 unità cross section
Lunghezza serie storiche = 193
Variabile dipendente: A56

	Coefficiente	*Errore Std.*	*rapporto t*	*p-value*	
const	−4,88179	1,79376	−2,722	0,0066	***
A2	0,0745800	0,0186129	4,007	<0,0001	***
A3	−0,177597	0,0625079	−2,841	0,0045	***
A4	1,00511	0,266675	3,769	0,0002	***
A5	−0,0637404	0,0294987	−2,161	0,0308	**
A6	−0,162892	0,0638479	−2,551	0,0108	**
A11	−0,958023	0,167998	−5,703	<0,0001	***
A13	−7,17907	3,86043	−1,860	0,0631	*
A16	−0,0869109	0,0384662	−2,259	0,0240	**
A19	0,00176400	0,000395658	4,458	<0,0001	***
A22	0,0945346	0,0255597	3,699	0,0002	***
A23	0,214848	0,0230744	9,311	<0,0001	***
A46	0,0868082	0,0336826	2,577	0,0100	**
A57	0,490160	0,0276582	17,72	<0,0001	***

Media var. dipendente	16,05941	SQM var. dipendente	28,36472
Somma quadr. residui	1038712	E.S. della regressione	23,33846
R-quadro LSDV	0,330723	R-quadro intra-gruppi	0,321526
LSDV F(22, 1907)	42,83387	P-value(F)	1,5e-148
Log-verosimiglianza	−8806,680	Criterio di Akaike	17659,36
Criterio di Schwarz	17787,36	Hannan-Quinn	17706,44
rho	0,681817	Durbin-Watson	0,626149

Test congiunto sui regressori -
Statistica test: F(13, 1907) = 69,5168
con p-value = P(F(13, 1907) > 69,5168) = 3,95579e-150

Test per la differenza delle intercette di gruppo -
Ipotesi nulla: i gruppi hanno un'intercetta comune
Statistica test: F(9, 1907) = 2,89711
con p-value = P(F(9, 1907) > 2,89711) = 0,00208591



Modello 11: Effetti casuali (GLS), usando 1930 osservazioni

Con trasformazione di Nerlove

Incluse 10 unità cross section

Lunghezza serie storiche = 193

Variabile dipendente: A56

	Coefficiente	*Errore Std.*	*z*	*p-value*	
const	−4,73448	2,02671	−2,336	0,0195	**
A2	0,0753872	0,0185780	4,058	<0,0001	***
A3	−0,175498	0,0623358	−2,815	0,0049	***
A4	1,01165	0,265618	3,809	0,0001	***
A5	−0,0662945	0,0292800	−2,264	0,0236	**
A6	−0,161150	0,0634373	−2,540	0,0111	**
A11	−0,936957	0,167248	−5,602	<0,0001	***
A13	−7,85593	3,83028	−2,051	0,0403	**
A16	−0,0905581	0,0382913	−2,365	0,0180	**

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A19	0,00171496	0,000394253	4,350	<0,0001	***
A22	0,0890458	0,0254011	3,506	0,0005	***
A23	0,217290	0,0230002	9,447	<0,0001	***
A46	0,0878168	0,0335917	2,614	0,0089	***
A57	0,488089	0,0274816	17,76	<0,0001	***

Media var. dipendente	16,05941	SQM var. dipendente	28,36472
Somma quadr. residui	1053647	E.S. della regressione	23,44426
Log-verosimiglianza	−8820,457	Criterio di Akaike	17668,91
Criterio di Schwarz	17746,83	Hannan-Quinn	17697,57
rho	0,681817	Durbin-Watson	0,626149

Varianza 'between' = 8,95937

Varianza 'within' = 538,192

Theta usato per la trasformazione = 0,512798

Test congiunto sui regressori -

Statistica test asintotica: Chi-quadro(13) = 907,388

con p-value = 1,32294e-185

Test Breusch-Pagan -

Ipotesi nulla: varianza dell'errore specifico all'unità = 0

Statistica test asintotica: Chi-quadro(1) = 9,68868

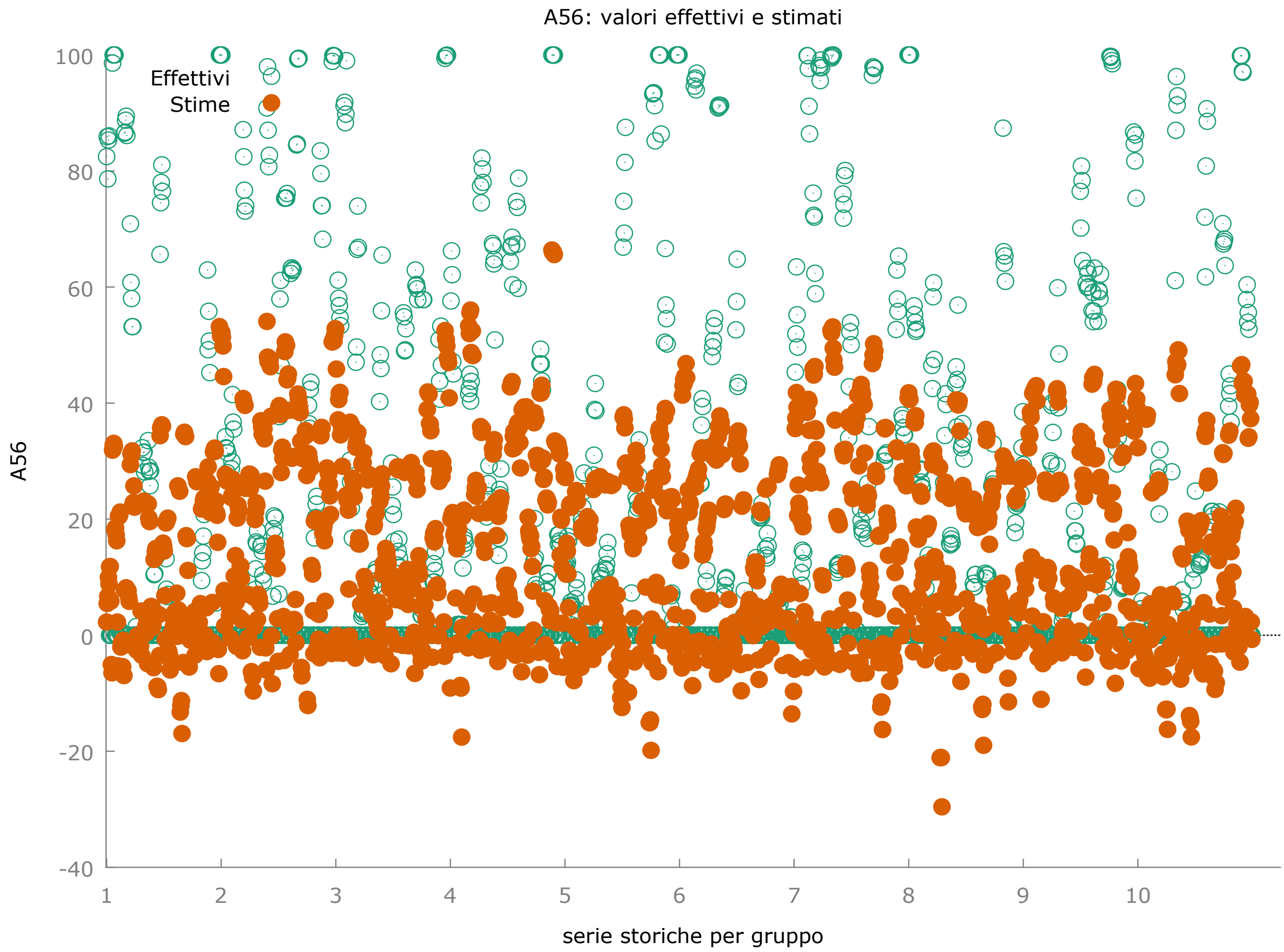
con p-value = 0,00185406

Test di Hausman -

Ipotesi nulla: le stime GLS sono consistenti

Statistica test asintotica: Chi-quadro(9) = 6,70427

con p-value = 0,667878



Modello 12: Pooled OLS, usando 1930 osservazioni

Incluse 10 unità cross section

Lunghezza serie storiche = 193

Variabile dipendente: A56

	Coefficiente	*Errore Std.*	*rapporto t*	*p-value*	
const	−4,33235	1,78904	−2,422	0,0155	**
A2	0,0777703	0,0185996	4,181	<0,0001	***
A3	−0,169882	0,0622482	−2,729	0,0064	***
A4	1,02262	0,264291	3,869	0,0001	***
A5	−0,0742075	0,0288251	−2,574	0,0101	**
A6	−0,156117	0,0626306	−2,493	0,0128	**
A11	−0,877988	0,166190	−5,283	<0,0001	***
A13	−9,73759	3,76814	−2,584	0,0098	***
A16	−0,100425	0,0380519	−2,639	0,0084	***
A19	0,00157848	0,000392871	4,018	<0,0001	***
A22	0,0735338	0,0251197	2,927	0,0035	***
A23	0,223928	0,0229445	9,760	<0,0001	***
A46	0,0913670	0,0335459	2,724	0,0065	***
A57	0,483126	0,0271631	17,79	<0,0001	***

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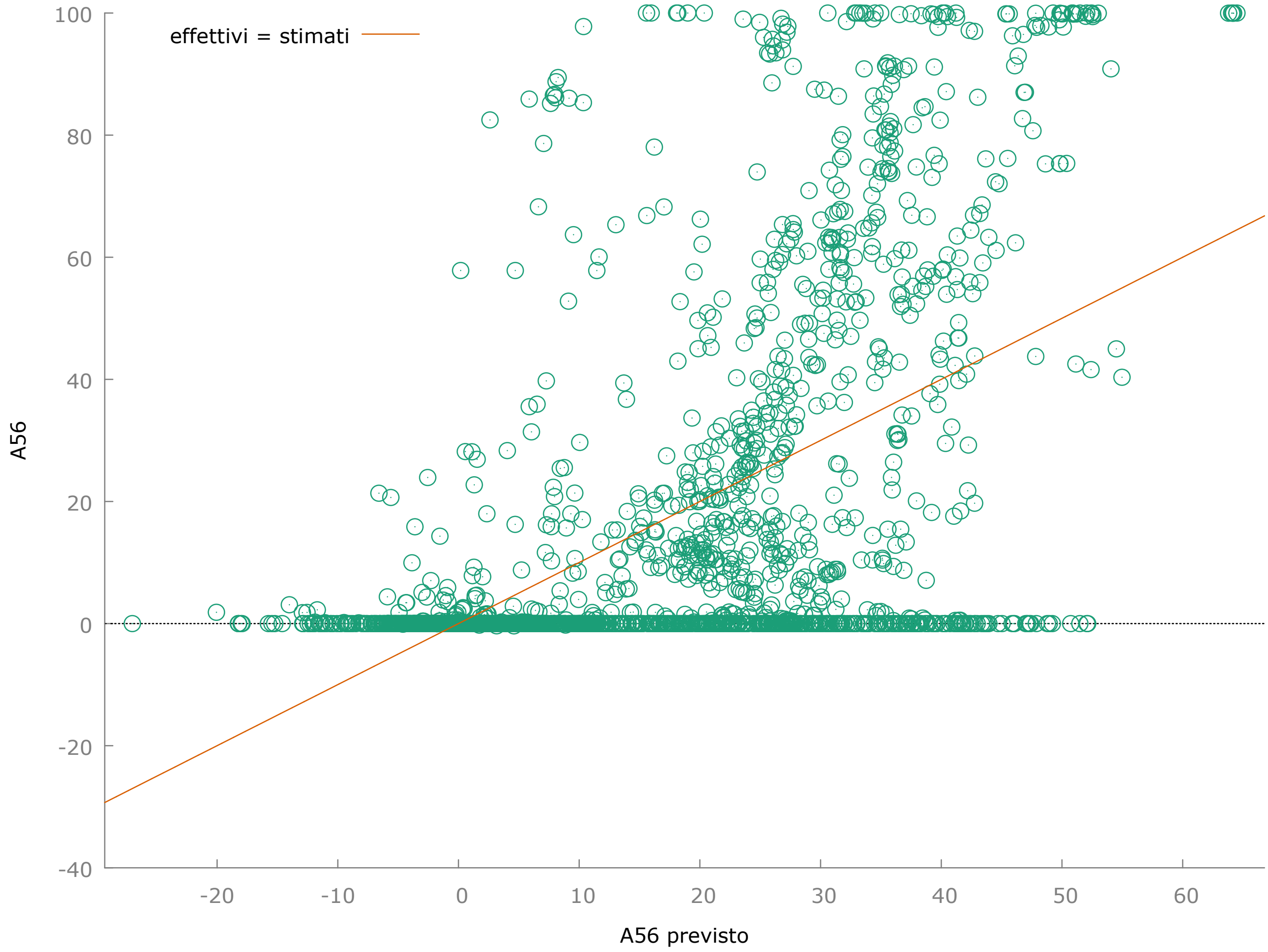
Media var. dipendente	16,05941	SQM var. dipendente	28,36472
Somma quadr. residui	1052914	E.S. della regressione	23,44221
R-quadro	0,321573	R-quadro corretto	0,316969
F(13, 1916)	69,85985	P-value(F)	6,6e-151
Log-verosimiglianza	−8819,785	Criterio di Akaike	17667,57
Criterio di Schwarz	17745,48	Hannan-Quinn	17696,23
rho	0,685349	Durbin-Watson	0,619448



Modello 13: WLS, usando 1930 osservazioni

Incluse 10 unità cross section

Variabile dipendente: A56

Pesi basati sulle varianze degli errori per unità

	Coefficiente	*Errore Std.*	*rapporto t*	*p-value*	
const	−4,34168	1,74370	−2,490	0,0129	**
A2	0,0777161	0,0180983	4,294	<0,0001	***
A3	−0,162341	0,0632533	−2,567	0,0103	**
A4	1,01344	0,271583	3,732	0,0002	***
A5	−0,0753037	0,0279943	−2,690	0,0072	***

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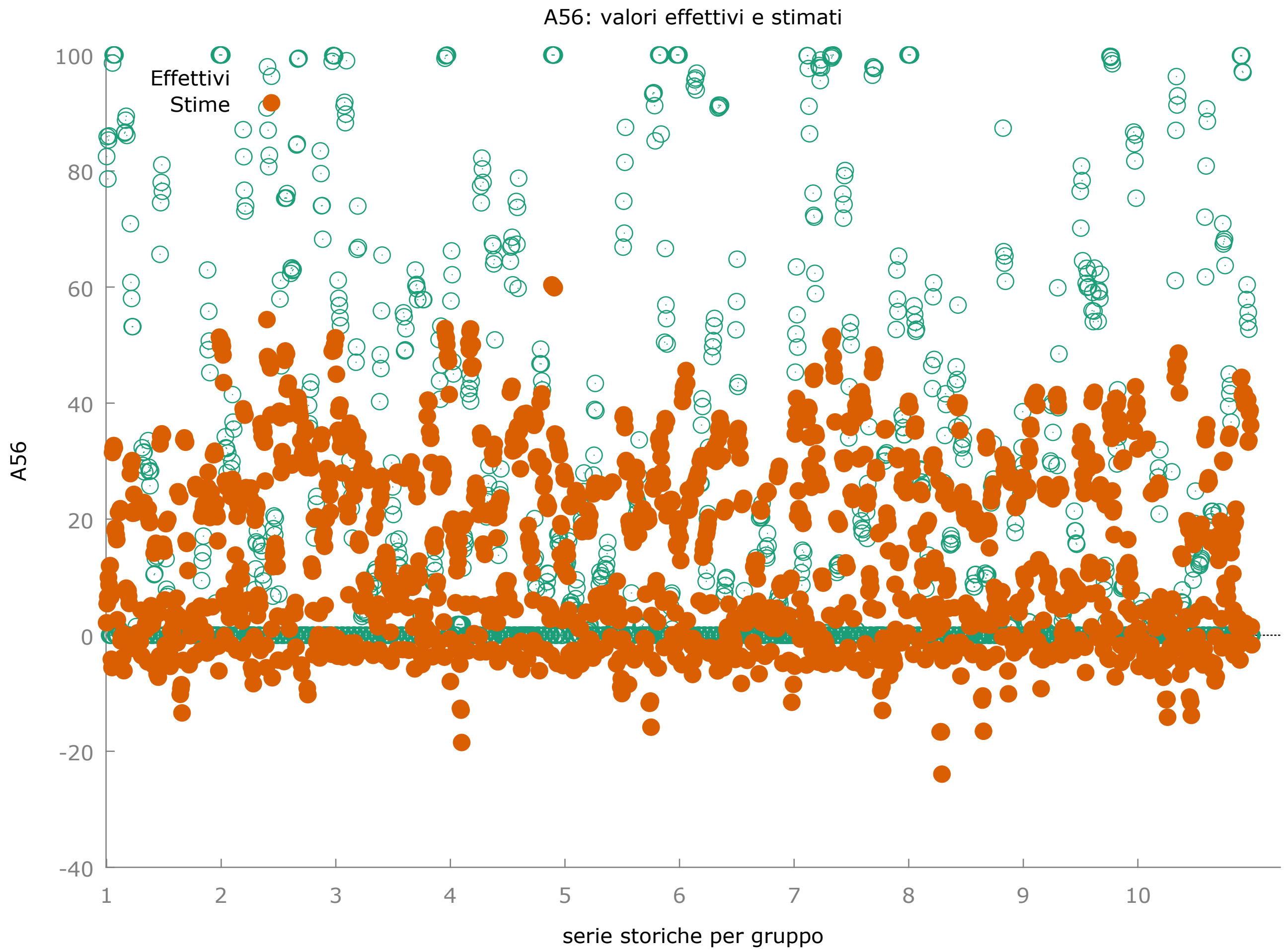
A6	−0,127972	0,0599907	−2,133	0,0330	**
A11	−0,784470	0,156773	−5,004	<0,0001	***
A13	−8,73999	3,67665	−2,377	0,0175	**
A16	−0,0745035	0,0369599	−2,016	0,0440	**
A19	0,00131690	0,000363949	3,618	0,0003	***
A22	0,0595175	0,0245179	2,428	0,0153	**
A23	0,217550	0,0221667	9,814	<0,0001	***
A46	0,0750692	0,0329968	2,275	0,0230	**
A57	0,484889	0,0264883	18,31	<0,0001	***

Statistiche basate sui dati ponderati:

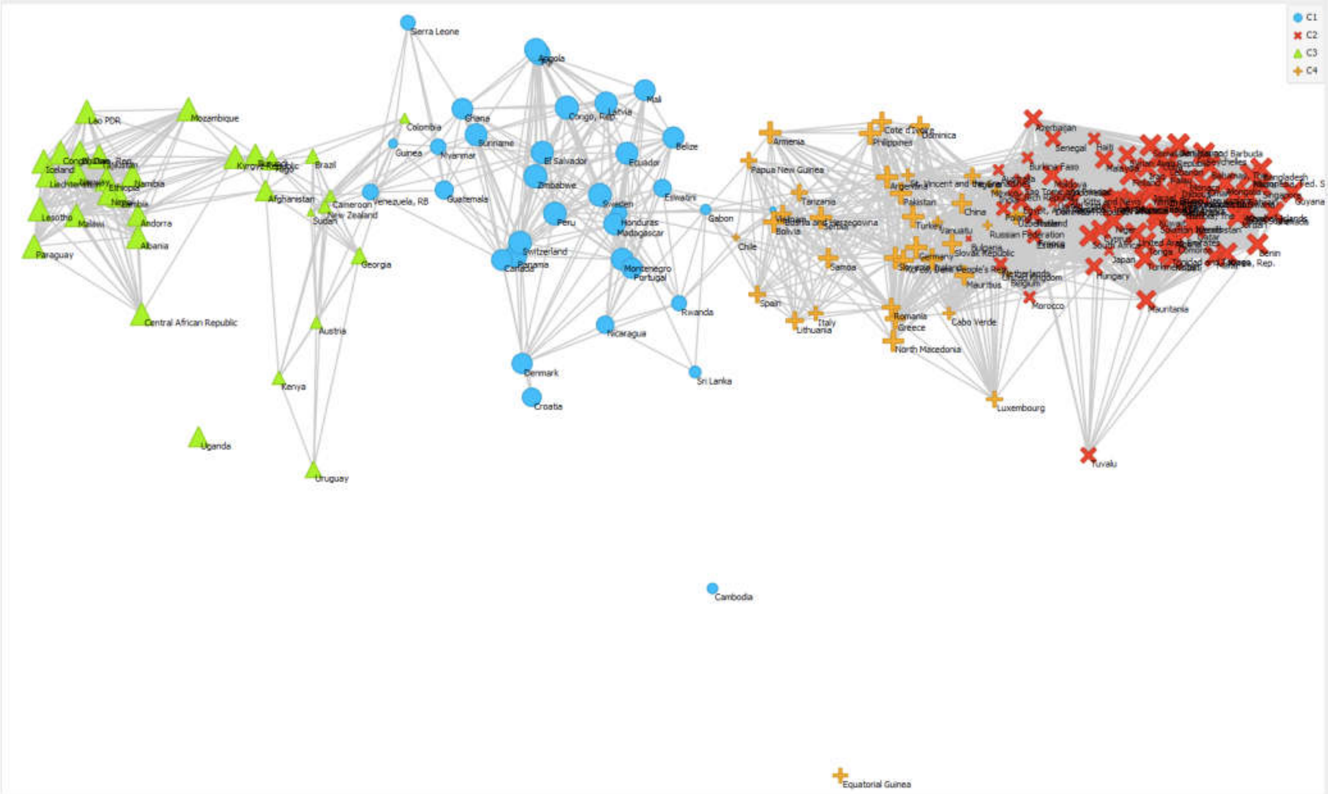
Somma quadr. residui	1927,509	E.S. della regressione	1,002999
R-quadro	0,323159	R-quadro corretto	0,318567
F(13, 1916)	70,36912	P-value(F)	7,2e-152
Log-verosimiglianza	−2737,305	Criterio di Akaike	5502,610
Criterio di Schwarz	5580,524	Hannan-Quinn	5531,270

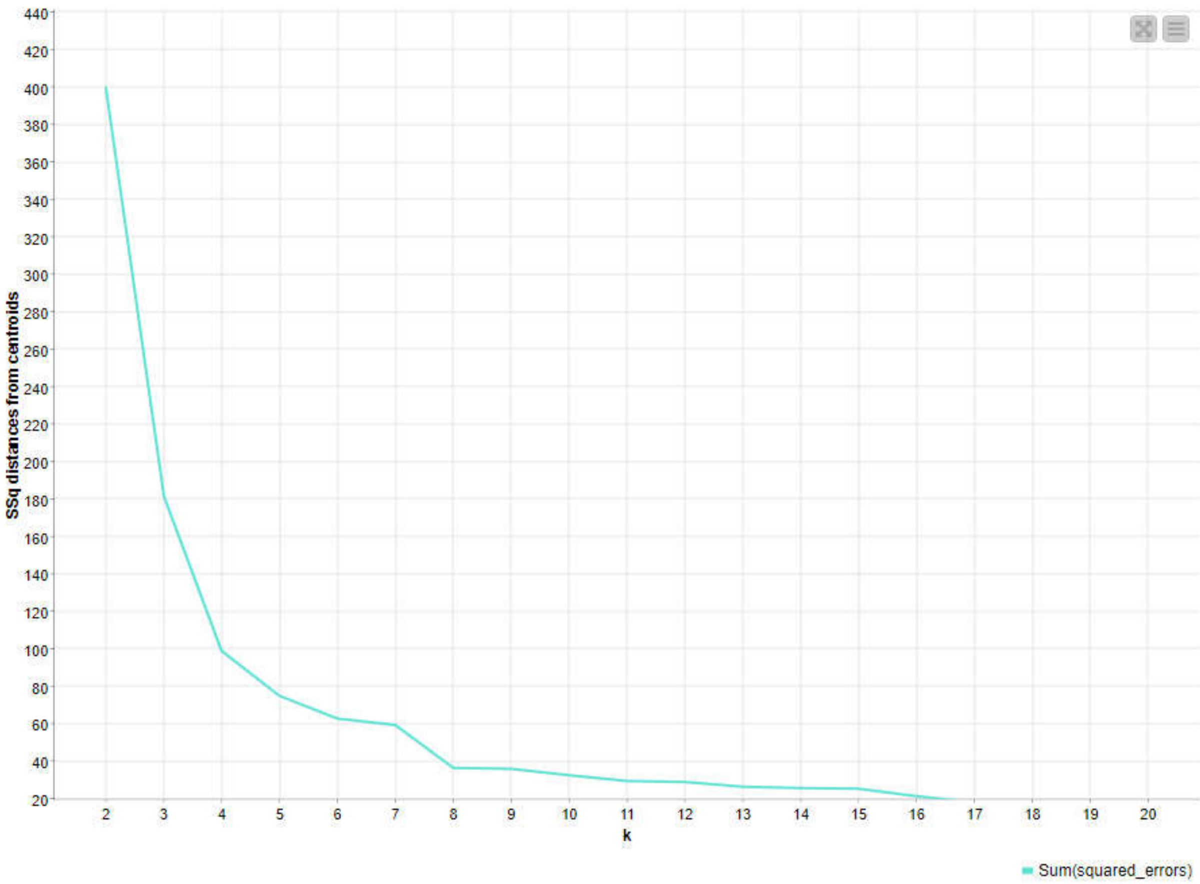
Statistiche basate sui dati originali:

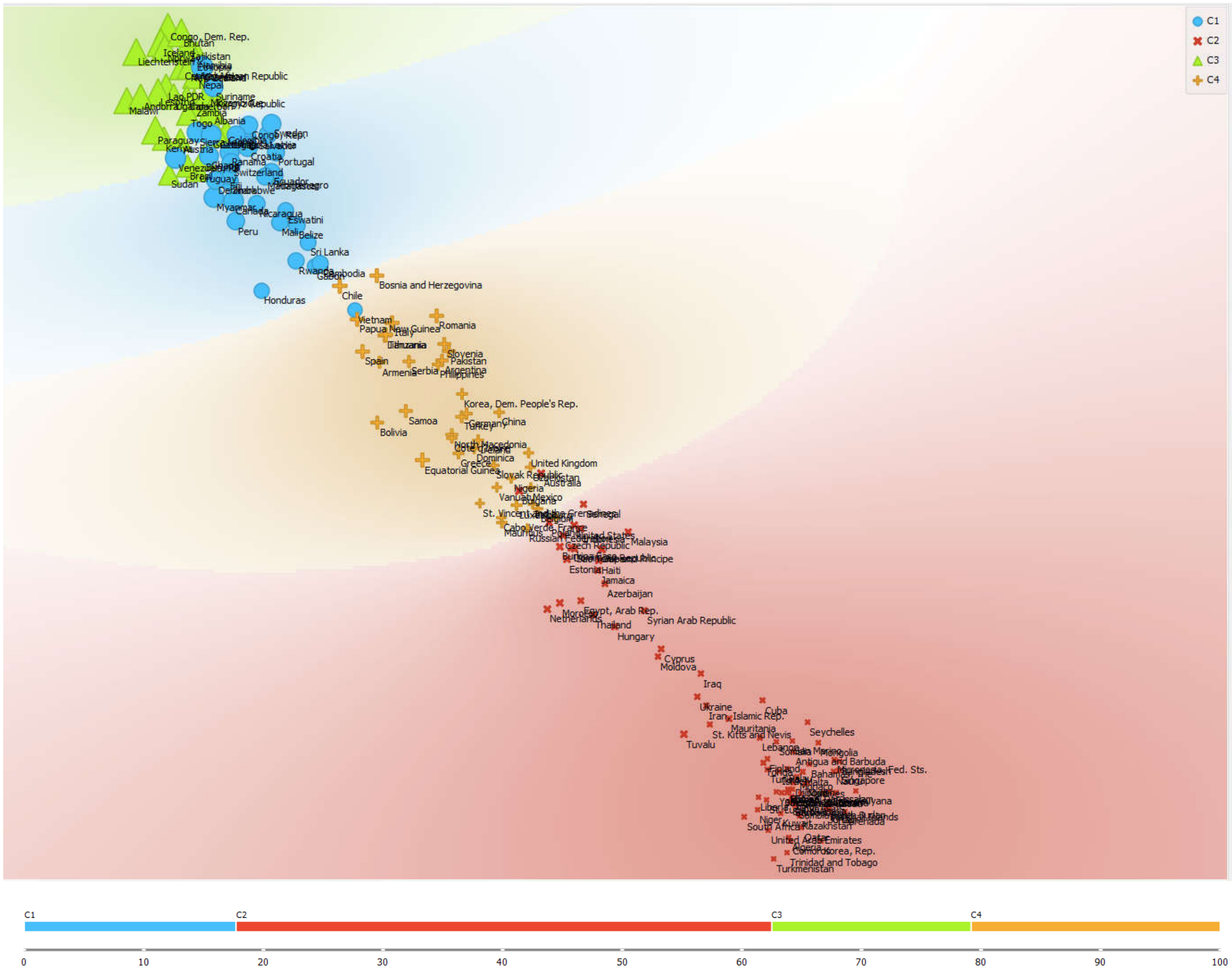
Media var. dipendente	16,05941	SQM var. dipendente	28,36472
Somma quadr. residui	1054163	E.S. della regressione	23,45612



Clusterization


C1
C2
C3
C4


SSq distances from centroids
k
Sum(squared_errors)


C1
C2
C3
C4
Congo, Dem. Rep.
Bhutan
Iceland
Liechtenstein
Nepal
Suriname
Malawi
Andorra
Lao PDR
Zambia
Togo
Albania
Paraguay
Kenya
Austria
Croatia
Portugal
Panama
Switzerland
Venezuela
Uruguay
Sudan
Myanmar
Nicaragua
Eswatini
Peru
Mali
Belize
Sri Lanka
Rwanda
Cambodia
Honduras
Chile
Bosnia and Herzegovina
Vietnam
Papua New Guinea
Romania
Italy
Tanzania
Slovenia
Pakistan
Spain
Armenia
Serbia
Argentina
Philippines
Korea, Dem. People's Rep.
Samoa
Turkey
China
Bolivia
North Macedonia
Dominica
United Kingdom
Greece
Equatorial Guinea
Slovak Republic
Australia
Nigeria
Mexico
Senegal
Malaysia
Czech Republic
Estonia
Haiti
Jamaica
Azerbaijan
Egypt, Arab Rep.
Morocco
Netherlands
Thailand
Syrian Arab Republic
Hungary
Cyprus
Moldova
Iraq
Ukraine
Iran, Islamic Rep.
Cuba
Mauritania
St. Kitts and Nevis
Seychelles
Tuvalu
Lebanon
Mongolia
Antigua and Barbuda
Micronesia, Fed. Sts.
Singapore
Guyana
Kazakhstan
South Africa
Niger
United Arab Emirates
Algeria
Comoros
Korea, Rep.
Trinidad and Tobago
Turkmenistan
0
10
20
30
40
50
60
70
80
90
100

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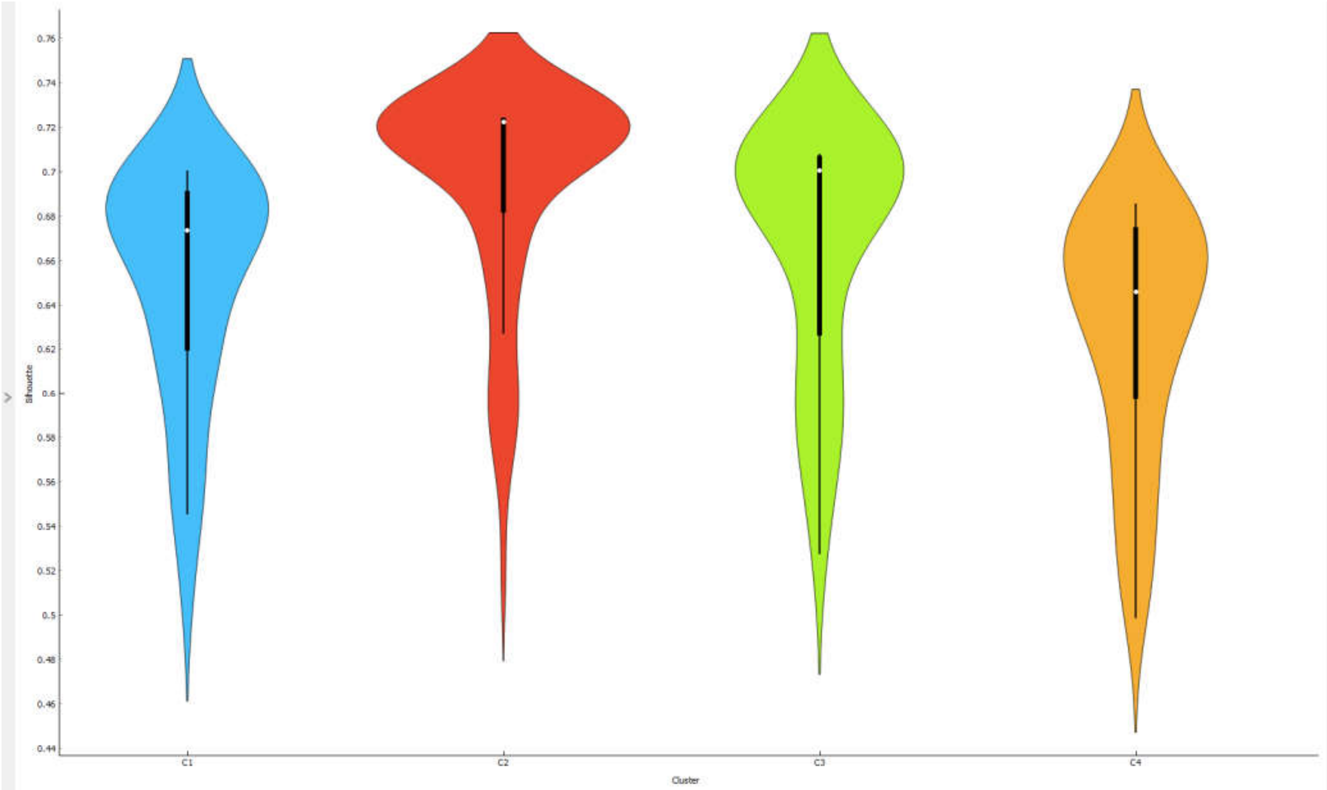
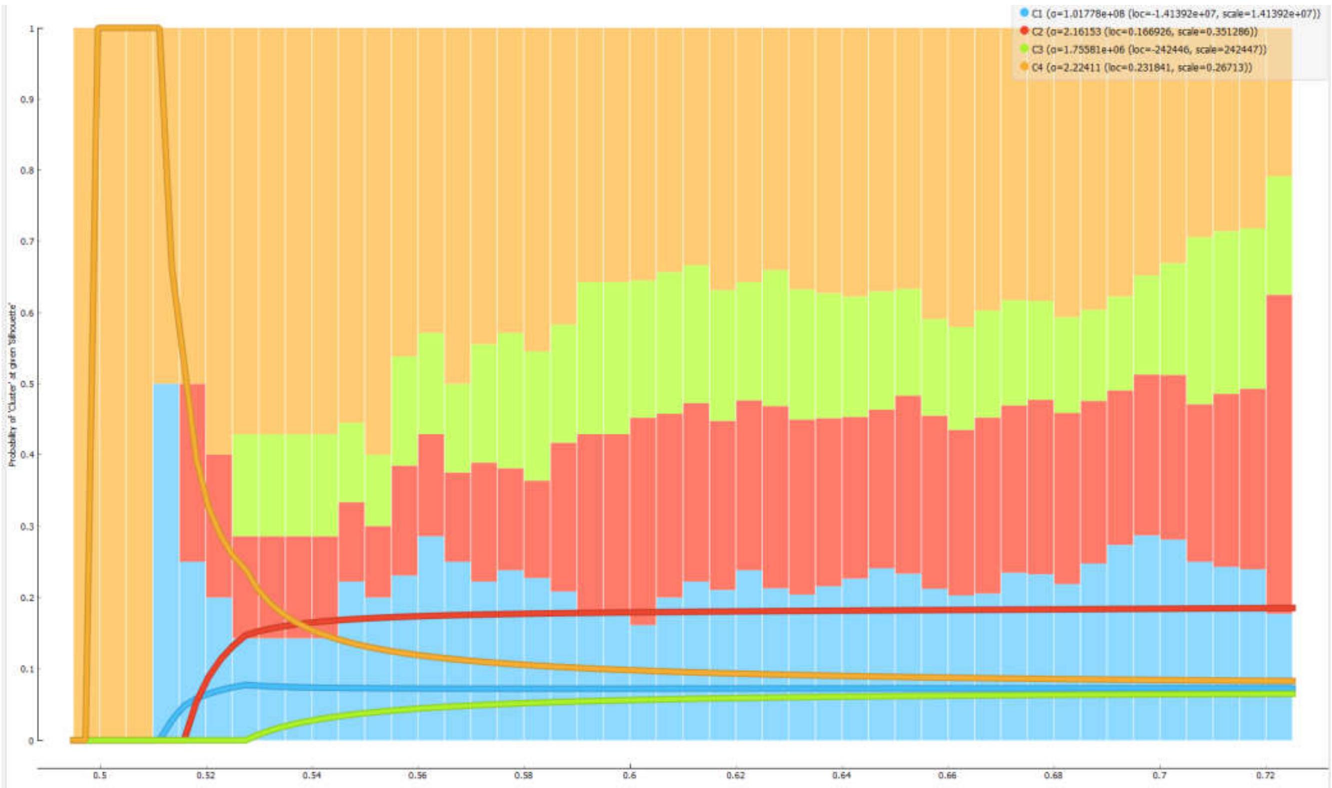
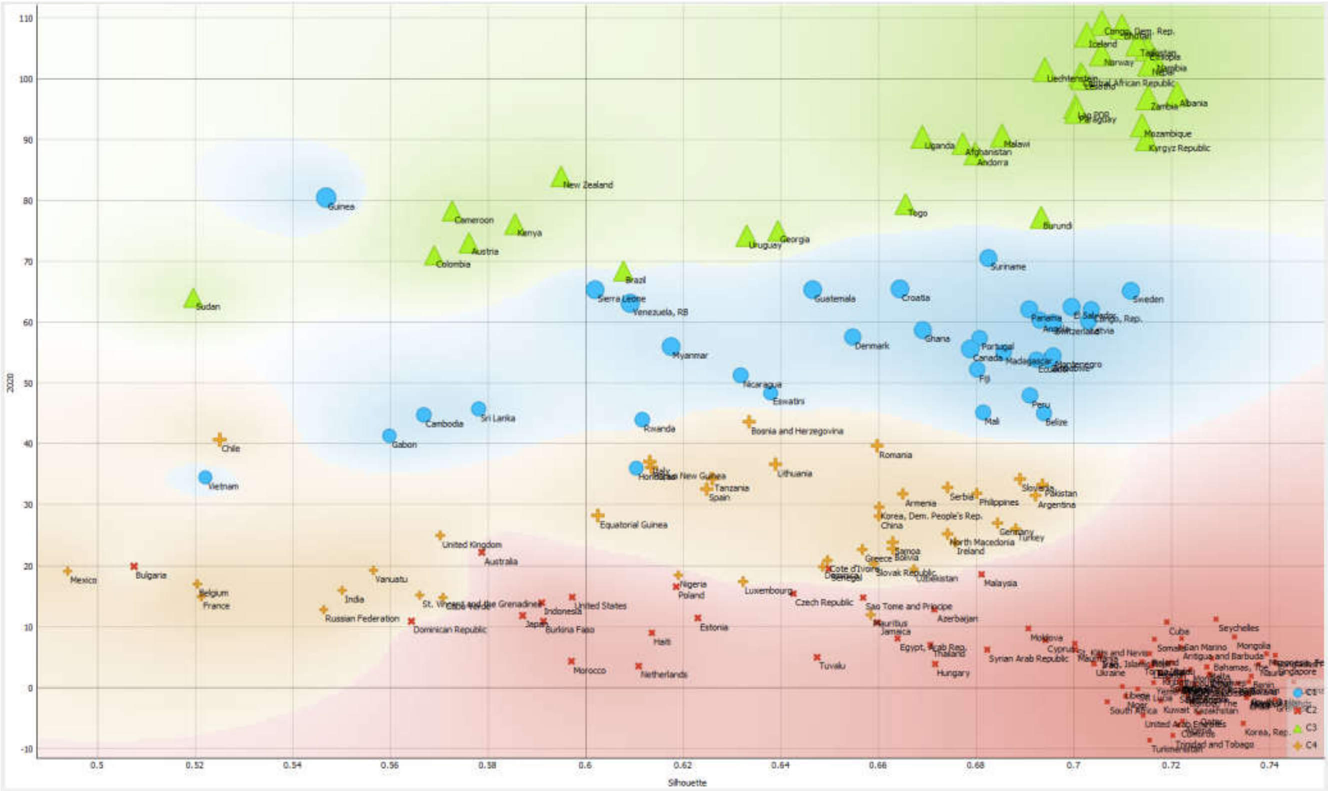
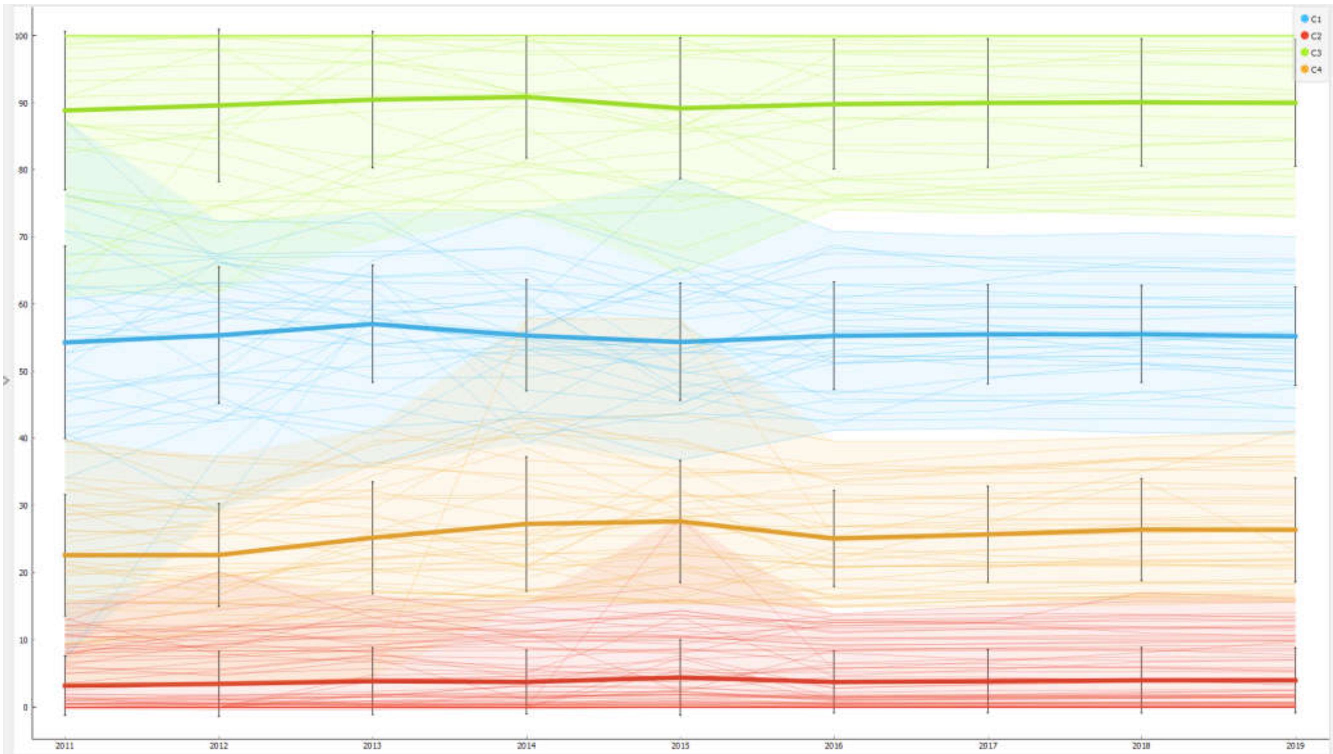
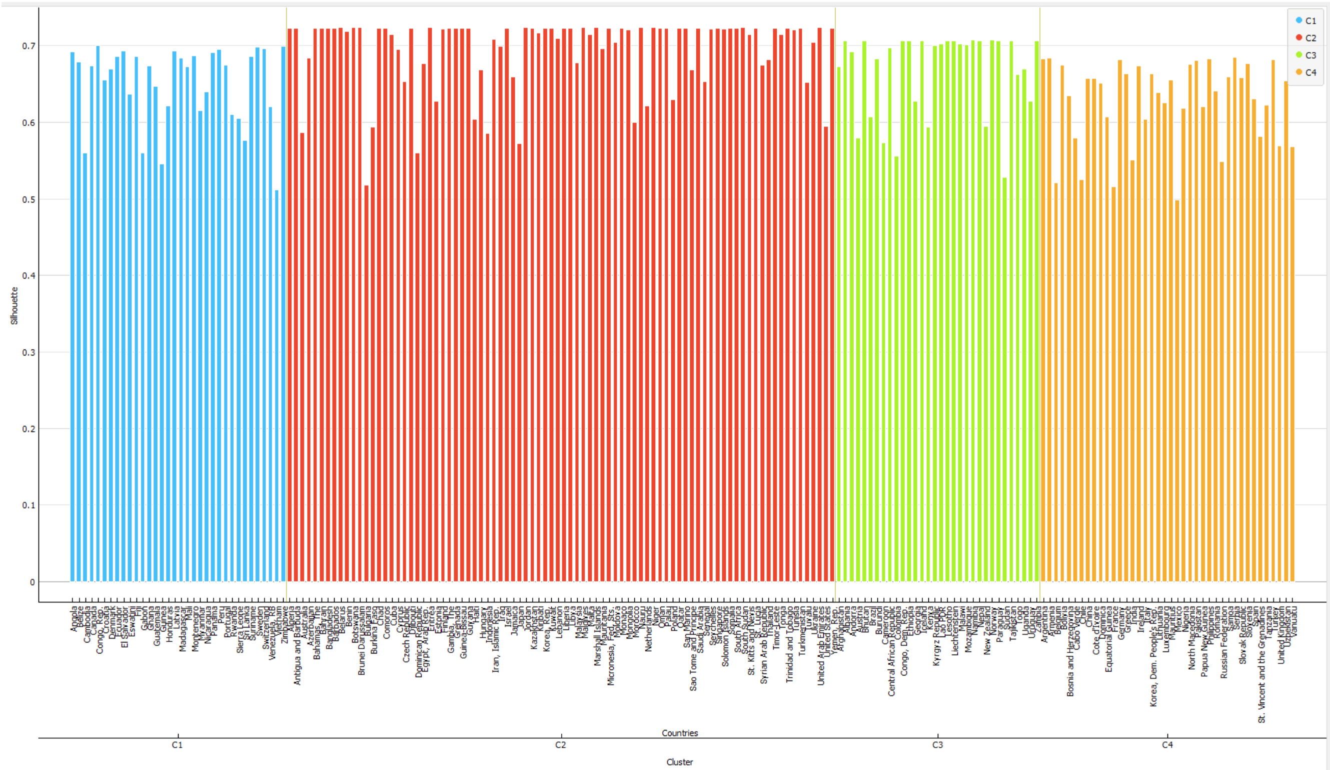





Silhouette
2020
C1
C2
C3
C4
New Zealand
Guinea
Cameroon
Kenya
Austria
Colombia
Sudan
Uruguay
Georgia
Brazil
Sierra Leone
Venezuela, RB
Guatemala
Croatia
Suriname
Sweden
Uganda
Afghanistan
Andorra
Malawi
Togo
Burundi
Liechtenstein
Iceland
Norway
Albania
Zambia
Mozambique
Kyrgyz Republic
Paraguay
Denmark
Ghana
Myanmar
Nicaragua
Eswatini
Fiji
Peru
Mali
Belize
Cambodia
Sri Lanka
Gabon
Rwanda
Chile
Vietnam
Bosnia and Herzegovina
Lithuania
Romania
Tanzania
Spain
Equatorial Guinea
Armenia
Serbia
Philippines
Slovenia
Pakistan
Argentina
Korea, Dem. People's Rep.
China
Germany
Turkey
North Macedonia
Ireland
United Kingdom
Australia
Mexico
Bulgaria
Belgium
France
Vanuatu
India
Russian Federation
Dominican Republic
Indonesia
United States
Burkina Faso
Nigeria
Poland
Luxembourg
Czech Republic
Estonia
Haiti
Morocco
Netherlands
Tuvalu
Slovak Republic
Uzbekistan
Malaysia
Sao Tome and Principe
Azerbaijan
Mauritius
Jamaica
Egypt, Arab Rep.
Thailand
Hungary
Syrian Arab Republic
Moldova
Cyprus
Ukraine
Cuba
Seychelles
Mongolia
San Marino
Antigua and Barbuda
South Africa
Kuwait
Kazakhstan
United Arab Emirates
Comoros
Korea, Rep.
Trinidad and Tobago
Turkmenistan
Singapore


C1
C2
C3
C4
2011
2012
2013
2014
2015
2016
2017
2018
2019



Machine Learning and Predictions

Machine Learning and Predictions					
Algorithm	***R^2***	***Mean absolute error***	***Mean squared error***	***Root mean squared error***	***Mean signed difference***
ANN	0,98422639	0,02228206	0,00142588	0,03776077	0,02028357
PNN	0,97436019	0,02498706	0,00227413	0,04768785	0,01145628
Gradient Boosted Trees Regression	0,99725160	0,00755937	0,00000000	0,01506067	-0,00489368
Tree Ensemble Regression	0,99801866	0,00950504	0,00000000	0,01510399	-0,00541064
Linear Regression Learner	0,99999811	0,00000000	0,00000000	0,00000000	0,00000000
Polynomial Regression	0,99886986	0,00154827	0,00000000	0,01084067	-0,00131967
Simple Regression Tree	0,99316964	0,01540092	0,00100000	0,02543195	-0,00469655

Ranking of algorithms by value of statistical error minimization and R-squared maximization					
Algoritmo	*R^2*	*Mean Absolute Error*	*Mean squared Error*	*Root Mean squared Error*	*Totale*
Linear Regression	1	1	1	1	4
Polynomial Regression	2	2	1	2	7
Gradient Boosted Trees Regression	3	3	1	3	11
Tree Ensemble Regression	4	4	1	4	12
Simple Regression Tree	5	5	2	5	17
ANN	6	6	3	6	21
PNN	7	7	4	7	25

Country	**2020**	**Prediction**	**Var Ass**	**Var Per**
Antigua and Barbuda	0,10	0,11	0,01	10,00
Armenia	28,20	28,18	-0,02	-0,07
Bahrain	0,00	0,00	0,00	0,00
Barbados	0,00	0,00	0,00	0,00
Belarus	0,74	0,72	-0,02	-3,03

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Botswana	0,04	0,07	0,03	64,33
Brazil	76,24	76,21	-0,03	-0,04
Brunei Darussalam	0,05	0,06	0,01	28,00
Burkina Faso	11,66	11,65	-0,01	-0,11
Burundi	85,53	85,40	-0,13	-0,15
Cabo Verde	18,48	18,49	0,00	0,03
China	22,01	22,99	0,98	4,45
Colombia	72,98	72,97	-0,01	-0,01
Comoros	0,00	0,00	0,00	0,00
Congo, Dem. Rep.	99,79	99,76	-0,03	-0,03
Czech Republic	10,69	10,69	0,00	0,02
Dominica	20,52	20,49	-0,03	-0,16
Dominican Republic	13,25	13,25	0,00	-0,02
El Salvador	59,34	59,35	0,01	0,02
Eritrea	0,52	5,53	5,01	963,08
Eswatini	46,93	46,95	0,02	0,04
Gabon	42,93	42,40	-0,53	-1,23
Georgia	78,78	78,79	0,01	0,01
Germany	26,26	26,25	-0,01	-0,03
Greece	24,54	24,56	0,02	0,08
Haiti	10,95	10,96	0,01	0,11
Honduras	44,59	44,59	0,00	0,00
Italy	37,99	37,00	-0,99	-2,61
Kazakhstan	0,14	1,91	1,77	1267,14
Korea, Rep.	1,68	1,60	-0,09	-5,06
Lao PDR	94,33	94,31	-0,02	-0,02
Lebanon	3,78	3,87	0,09	2,38
Luxembourg	23,48	23,50	0,02	0,10
Malaysia	9,11	9,24	0,13	1,43
Malta	4,35	4,52	0,17	3,91
Marshall Islands	0,23	2,23	2,00	868,70
Mauritania	7,47	7,02	-0,45	-6,02
Mexico	15,25	15,23	-0,02	-0,13
Moldova	5,78	5,77	-0,01	-0,17
Monaco	0,00	0,00	0,00	0,00
Niger	0,66	6,66	6,00	908,79
Nigeria	18,55	18,55	0,00	-0,01
Peru	53,46	53,45	-0,01	-0,02
Poland	12,11	12,09	-0,02	-0,17
Qatar	0,00	0,00	0,00	0,00
Russian Federation	16,20	16,19	-0,01	-0,06
Rwanda	48,18	48,17	-0,01	-0,02

Sao Tome and Principe	9,71	9,17	-0,54	-5,56
Seychelles	1,79	1,08	-0,71	-39,72
Sierra Leone	64,94	64,89	-0,05	-0,08
St. Kitts and Nevis	4,23	4,19	-0,04	-0,95
Timor-Leste	0,00	0,00	0,00	0,00
Trinidad and Tobago	0,00	0,00	0,00	0,00
Tuvalu	11,68	11,66	-0,02	-0,14
Uganda	90,23	90,24	0,01	0,01
United Kingdom	19,16	19,16	0,00	0,00
Uruguay	83,14	83,10	-0,04	-0,05
Zimbabwe	54,88	54,84	-0,04	-0,07