

Article

Factors Influencing Energy Consumption in the Context of Sustainable Development

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Received: 1 July 2019; Accepted: 30 July 2019; Published: 1 August 2019



Abstract: Based on the global need to reduce the primary and final energy consumption, as part of the climate change mitigation strategy, the present study aims at determining the influence of different economic, social and environmental factors on the two types of consumption while emphasizing the importance of this topic for the research area. The novelty of the study resides in the factors considered in the panel analysis as well as in the combination of the analysis methods: the panel data analysis and the bibliometric analysis. The main results show that factors such as greenhouse gas emissions, gross domestic product, population and labour growth have a positive relationship with both primary and final energy consumption, which means an increase of energy consumption. Meanwhile, factors such as feminine population increase, healthcare expenditures or energy taxes have a negative relationship, which determine a reduction of energy consumption. The results should be of interest to the authorities in designing new energy reduction policies for contributing to sustainable development goals, as well as to the researchers.

Keywords: sustainable development; energy consumption; econometric model; bibliometric analysis; relationship

1. Introduction

The possibility of harnessing the free energy that surrounds us or that of reproducing it for providing light or heat has puzzled scientists for centuries. Either by burning some natural resources such as oil or coals or by experimenting ways of multiplying the natural lightening, people such as Thomas Edison [1], tried to satisfy their basic needs, those of heat and light. New inventions, such as Faraday's dynamometer in 1830 [2] allowed people to use electric power for building machines and finally, it represented the beginnings of the Industrial Revolution. This new era in the history of mankind proposed models for the development of society based on intense use of resources; it contributed to setting the world great powers, and along with development, there comes an increase in a country's energy consumption [3].

Yet, the Industrial Revolution also had side effects, on economic, social and environmental levels. Those countries which could afford to invest in developing the industrial sector are still economic world leaders, a fact that roots social disparities [4] and those which are currently developing are expected to increase their energy consumption [3,5] since there is an obvious relationship between energy consumption and economic growth [5]. This also caused severe environmental damage, understood

mostly by climate changes [6]. Some experts use the term eco-crisis to describe the recently formed economic and ecologic relationship [7].

Since the 1970s [8] the attention was drawn to the major global growth drivers of eco-crisis, namely: Population, agriculture, industry, social inequality, natural resources, including energy resources, and pollution. Since then, several experts have turned their attention on the relationship between energy consumption and economic factors influenced by it [9] or on energy consumption and environmental factors [10,11].

Even more, it is worldwide acknowledged that energy consumption must be reduced in order to mitigate the climatic changes that constantly occur because of it. The United Nations, through their 2015 sustainable development strategy named the 2030 Agenda has developed a set of 17 sustainable development goals [12], number seven in this set of goals is refereeing directly to the energy sector: “Affordable and clean energy”. This goal has two sides, one of them related to increasing the accessibility to electric power for the poor or isolated communities, and the second side, related to increasing the percentage of renewable energy sources in the total consumption of energy and even replacing conventional energy with renewable energy production.

Undoubtedly, the holistic management of the resources plays a key role in meeting sustainability goals, and the energy sector is an important part of this puzzle. The current situation of environmental degradation manifested by the overexploitation of energy resources and the intensification of climate change, known as the eco-crisis, occurred on the background of the Industrial Revolution.

Yet, we must ask ourselves, what are the critical influencers of the energy sector? Where should we focus in order to develop a sustainable energy sector? There are also other experts who contribute to solving these questions [13–17] by studying the relationship between energy consumption and gross domestic product. However, some of the results are inconclusive or mixed and they heavily depend on the indicators considered and the methodology chosen.

Therefore, the need for retesting some of the already analysed variables is obvious, as it is the inclusion of new indicators and indices of the social, economic and environmental system in previous models, which have not been tested yet [18].

In this case, this study aims to assess the energy determinants at European Members level (EU28) through a holistic approach of the system (including all the areas: Economic, social, environmental, etc.) in order to identify critical points (some not yet explored) which influence the sustainability of the energy sector.

The constructed models consider the literature in the field, as well as the testing of new determinants of the considered endogenous variables.

The data was gathered from several data bases: Eurostat [19], World Bank [20] and the Energy Information Administration—EIA [21]. The multitude and diversity of the indicators analysed, and the models considered are a necessary contribution to substantiate the proposals to improve the European Union energy and climate targets and policies. The region was chosen due to the availability of the data, as well as for the historic importance and the presence of both developed and developing economies.

A first objective of the research is to analyse whether the relationship between the energy consumption, emissions and the economic sector poses an interest for the researchers, through a bibliometric analysis of the articles available on the Web of Science database.

The second objective is to analyse the factors that should be prioritized in order to reduce energy consumption at EU28 level for mitigating climate change and reducing the risk of worsening social welfare.

The final objective is to highlight the implications of research on sustainable energy policies at a European level.

The present paper is structured into four main sections. The first section presents the main findings in the literature on this topic, which are relevant for the current discussion. The second section regards the chosen methodology and presents the construction of the present analysis and models. The third section presents the main findings of the research and it is structured in three main subsections,

first presenting the results of the bibliometric analysis, second, presenting the results of the panel data models on the primary energy consumption and third, presenting the results of the panel data models on the final energy consumption. The fourth section discusses the obtained results by comparing them with other relevant studies and by providing a series of recommendations. The paper ends with a concluding section.

2. Literature Review

The causality between energy consumption and economic growth has been approached by several authors. For example, the study of Caraiani et al. [15] confirms the causality between primary energy consumption from different sources and gross domestic product for Bulgaria, Poland, Romania, Hungary and Turkey between 1980 and 2012/2013. Paul and Bhattacharya [22] studied the relationship between economic growth and energy consumption in India for the 1950–1996 period and they found that there is both a bidirectional causality and same direction causality between the two variables. Asafu-Adjaye [9] proves in his study on Indonesia, India, Thailand and the Philippines that the relationship between energy and income is not a neutral one, hence, energy consumption is influenced by the income variation. A similar observation is made by Aqeel and Butt [23] who prove that the economic growth of a country directly influences the growth of petroleum consumption in that country.

Other experts [10,24,25] demonstrate, with different approaches, that carbon emissions and energy consumption do not lead to economic growth, so their suggestion to the authorities is to pursue energy conservative policies and carbon reduction policies since they don't interfere with the economic development of a country. Their results are very important for supporting the global strategies of energy consumption reduction.

Another study [26] aims at determining the existing relations between the energy consumption from different energy sources and the economic growth in the case of Romania, Spain and the EU27 average, on short and long term. The authors [26] prove the existence of unidirectional relations from energy consumption towards gross domestic product (GDP), notably the causal influence of renewable energy consumption on economic growth in Romania and Spain. On the other hand, Aspergis and Payne [27,28] find that there is a bidirectional causality between economic growth and renewable energy consumption, based on their studies on different sets of countries. Further studies of Aspergis and Payne [29] on a panel of 80 countries showed that there is a positive impact on real GDP from both renewable and non-renewable energy consumption, since there is only a small difference in the elasticity estimates of the renewable and non-renewable energy consumption.

Çoban and Topcu [16] investigate the effects of economic growth, energy prices and financial development indices on energy consumption at the EU27 level. At the same time, comparing the 15 older EU states with the 12 newer ones, they note that an increase in energy consumption due to higher financial development in the EU15 countries, as the rest of the member states have a less developed financial system, especially with regard to stock exchanges, which limits its impact on energy consumption. However, a poorly developed financial system produces negative effects on investments in energy efficient technologies, these effects being suggested by energy intensity above the EU average of the EU12 countries [16].

More recent studies [14] confirm the differences between developed and developing economies, showing that the use of energy from renewable sources has a higher influence on economic growth of the countries with higher GDP than for those with lower GDP.

Other approaches [30] show the influence of emissions, GDP, financial development, capital stock and population on energy consumption. In addition, Stadelmann and Castro [31] propose unusual indicators to be analysed in the estimation of energy consumption in relation to public policies in 106 states during 1998–2009.

The causality between carbon dioxide emissions, energy consumption, gross domestic product, and foreign direct investments is investigated by Kim [32] who claims that there is no direct short-term causality between foreign direct investments and CO₂ emissions, based on a study on 57 developing

countries in the 1980–2013 time frame. His results do not support the idea that foreign investments positively influence the CO₂ emissions. However, Nasir et al. [33] claim the contrary. By using a panel data analysis on data from 1982 to 2014 in five East-Asian economies, they [33] find that financial development, economic development and foreign direct investments have a statistically significant long-term relationship with environmental degradation represented by CO₂ emissions. In fact, financial development and foreign investments leads to an increase in environmental degradation.

By studying the relationship between energy consumption and economic growth in the countries known as BRICS (Brazil, Russia, India, China and South Africa), Baloch et al. [34] suggest that there might be a correlation between the abundance of natural energy resources and CO₂ emissions, based on a panel data study from 1990 to 2015. Their [34] results show that the abundance of resources mitigates the emissions in Russia, while in South Africa it increases them. Aydin [35] finds that in the same BRICS countries the increase of biomass energy consumption use would have positive results towards sustainable environment, economic growth and energy dependency reduction.

Salim et al. [36] uses a linear and non-linear econometric approach to see the effects of urbanization on pollutant emissions and energy intensity in developing economies of Asia. Their results show that population, prosperity, and non-renewable energy consumption are major influencers of pollutant emissions. A more important result is that for the countries which achieved a certain level of development, their emissions tend to decline.

While investigating the literature review on the methodology used for studies in this field, it was observed that the top-down methodological approaches on the evolution of environmental conditions and the energy sector take into account energy market components, but do not include technological development in the analysis, while bottom-up approaches use the model of overall balance to capture the determinants of change in the energy system and the natural environment, such as emissions, energy efficiency and technology, without considering the feedback from the economy [37]. These limits have led to the emergence of a mixed approach that suggests feedback, but due to the nature of the equilibrium models, it still fails to surprise those [37].

Considering the proposed policies suggested by different authors, we mention the Colombian case, where a low-carbon policy would preserve low emissions in electricity generation [37]. Other studies [38] use the non-causality in heterogeneous panel test to see if the exploitation of renewable energy sources in the EU-28 countries is an achievable solution for environmental pollution mitigation. Their results suggest that it is possible to reach the sustainable development goals until 2030 through renewable energy consumption and carbon emission mitigation, so they support the policies regarding renewable energy promotion. Some authors [39] support the idea that one policy could not work for each case, so a mixed policies approach should be considered based on the specificities of every country. Another study suggests a policy of rewarding the most efficient countries by granting them potential increases in emission and energy consumption while the least efficient countries must bring decreases to achieve full efficiency by applying the modelled reallocation [40].

According to Belke et al. [41], most of the current models for analysing energy relations and economic growth are based on the model of production functions such as Saidi and Hammami's [30] study, which, however, does not include the price of energy, as most studies in this area. Even so, the data panel is preferred over time series and cross-sectional analysis due to its higher accuracy by including binary variables that capture different time series and different cross-sectional units with the fixed or impact effects model [42]. On the other hand, the Wang et al. [43] study includes influence factors such as the following: Energy prices, urbanization and GDP on energy consumption through a panel data analysis on 186 countries between 1980–2015, and it finds that energy prices negatively affect the energy consumption in low-and medium-income countries. Also, the study finds that urbanization is a very important factor which affects energy consumption per capita. Also, Lv et al. [3] support the idea that urbanization influences carbon emissions from energy consumption, but due to the new ecological or green trends followed by the urban population, the urbanization has an alleviation effect on the emissions level.

In opposition to urbanization, there is another high energy consumption factor, namely agriculture. Harchaoui and Chatzimpiros [44] discuss the possibility of reducing the energy consumption in agriculture. Their results show that the current agricultural model is structurally energy deficient. Basically, its functional energy requirements are almost equal with the final production. The energy potential from manure and crop residues (as biomass) could only equal the external energy needs of agriculture [44]. For agriculture to become an energy source it is supposed to stop feeding from cropland and to reach the maximum amount possible from the agricultural residues [44]. Tian et al. [45] propose a more thoughtful choice of production ways to improve the sustainability of agriculture, by reducing the energy consumption. Their observations prove that the amount of energy consumed for growing the agricultural product is very high and unadjusted to the geographical conditions; however, it could be easily reduced by adjusting to the area of growing [45].

Other authors [46] go further to propose renewable energy sources along with a pros and cons evaluation of the source. The main reason against the alternative energy source (geothermal energy) is the high investment needed to turn it into a viable system, which makes it an option only for developed countries. Whereas, in countries like Turkey, where there is an abundance of geothermal sources, the rapidly growing population and economic growth do not allow for a stagnation in the use of pollutant energy sources (such as coals) and the investment in harnessing the renewable energy source [47]. After Temiz Dinç and Akdoğan [48] demonstrate a bidirectional causal relationship between renewable energy and economic growth based on 1980–2016 data, they claim that increasing renewable energy production and decreasing energy consumption are a must for ensuring Turkey's sustainable development. Some authors [49] come with solutions appropriate for reducing the final energy consumption, based on a multi criteria analysis on the case of Italy, which proves the efficiency of using solar thermal panels combined with the heat pumps instead of the current system used for providing hot water and heat.

Mostly based on panel data analysis, on longer or shorter periods, most of the studies demonstrate the negative effects of energy consumption over the environment, through the polluting effect it has, but also the fact that it does not affect the economic growth of a country in a significant way. In this case, most of the recommendations of the experts incline to designing new policies, which should integrate investments in renewable energy production and replacing non-renewable sources, mostly used in the current situation.

3. Materials and Methods

This study uses both bibliometric analysis and panel data techniques. The first method represents a quantitative analysis of the literature review in the field in order to emphasize the importance trend of a topic, as well as its main areas of interest. The bibliometric analysis is conducted on the 671 articles found on the Web of Science database, in the 1975–May 2019 time frame, by using terms such as “energy”, “emission*” and “economy” in the query and refining the results after the “relationship” filter word, in order to keep only the results which have a model included. After finding these articles on the Web of Science database, quantitative analysis was performed by investigating the trend of the scientific production in the field, the most prolific authors, the areas of interest, as well as the affiliated countries of the publications found on Web of Science. The method is useful in overviewing the previous results on the researched area, and it is constantly used in other studies [50,51]. Also, by using the Vosviewer software, the concepts mostly used in these articles and the relationships between them will be exposed [52]. This software creates word networks by analysing the title, the abstract and the keywords of research data from Web of Science. The limit of this technique is given by the fact that the information provided by the title, the abstract and the keywords of research data has a marketing purpose and, sometimes, it might reach subjects which are not thoroughly debated in the full corpus of the scientific publications. Nonetheless, the word networks give an overview of the areas of interests in the field.

Further, panel data is the econometric technique chosen to observe energy consumption determinants, as it is more comprehensive than time series or cross-sectional analysis [42]. In comparison with other studies in the field [17,30,53–56], this piece of research offers a more comprehensive analysis because of the numerous variables considered in the energy consumption influence analysis.

The estimation of the panels was conducted by testing the three methods explained by Wooldridge [57], namely: The common or non-effect constant method, implying assigning a common constant to all countries considered in the panel, not making the difference between states and periods; the fixed effect method, which allows the assignment of a fixed constant for each state/period, that is, the constant varies cross-sectional; and the random effect method, which allows the treatment of constants, which are not fixed for each state/period, as random parameters, which involve the inclusion of a new error due to differences in the fixed effect in the error term.

The multiple regression models include data on the categories of data presented in Tables 1–3.

Also, in the analysis was considered the square of GDP (GDP-2) in order to test the potential existence of a hyperbola shape.

Table 1. Eurostat variables used in the models [19].

Abbreviation	Explanation of the Variable	Measure Unit
PEC	Primary energy consumption	Thousand tons of oil equivalent
FEC	Final energy	Thousand tons of oil equivalent consumption
FFE *	Fossil fuels weight in total European Union (EU) internal gross energy consumption	%
RE *	The renewable energy weight in total EU internal gross energy consumption	%
NE *	Nuclear energy weight in total EU internal gross energy consumption	%
GHG	Greenhouse gas emissions	Thousand tons of CO ₂ equivalent
ENVT	Share of environmental taxes in gross domestic product (GDP)	%

* Part of the energy mix. Source: Our own abstracting of the considered factors.

Table 2. World Bank variables used in the models [20].

Abbreviation	Explanation of the Variable	Measure Unit
REL	Renewable electricity weight in total electricity production	%
NEL	Nuclear electricity weight in total electricity production	%
GDP	Gross domestic product	US\$ 2005 constant prices
IU	Internet users per 100 people	number
K	Capital stock	US\$ millions of 2010 constant prices
WF	Workforce	Thousand persons
PD	population density	persons/km ²
POP	Population	Thousand persons
K-GDP	Namely gross fixed capital formation as a share of GDP	%
EIMP	Net energy imports as a share of the total energy used by a country	%
C-GDP	Financial development assessed by the share of credits granted to the private sector in GDP	%
SE-GDP	Trade openness valued through stock exchanges as a share of GDP	%
EB-GDP	The external balance of goods services as a share of GDP	%
RD-GDP	Share of research and development expenditure in GDP	%
M-GDP	Share of military expenditure in GDP	%
AA	Agricultural area as a share of the total area of a country	%
NR-GDP	Renting natural resources as a share of GDP	%
UPOP	The share of urban population in the total population	%
FPOP	Proportion of the female population in the total population	%
FM	Female legislators, officials and managers in leading positions	%
WP	Proportion of women's mandates in national parliaments	%
TEDU	The share of labour that followed tertiary education in the total labour force	%
H-GDP	Share of health expenditure in GDP	%

Source: Our own abstracting of the considered factors.

Table 3. Energy Information Administration (EIA) variables used in the models [21].

Abbreviation	Explanation of the Variable	Measure Unit
EP	Oil price	Brent oil price for Europe-\$/barrel, transformed by applying the 2010 consumer price index

Source: Our own abstracting of the considered factors.

All these variables were chosen by investigating several scientific studies [16,17,30,53,58–63].

Our first hypothesis is that GDP, GHG (greenhouse gas emissions), the energy mix based on nuclear energy and fossil fuels, capital accumulation, financial development, trade opening, military development, internet access, agricultural area, population density, labour force, and the degree of urbanization has positive relationships with energy consumption, so it causes negative effects on the holistic system, which considers all three pillars of sustainable development: Economic, social and environmental.

At the same time, the use of renewable energy, the price of oil, net energy imports, research and development funding, environmental taxes, exhaustion of natural resources, female decision makers, health system financing and high level of education might have negative relationships with energy consumption, thus generating positive effects on the holistic system by reducing the use of energy. The more educated people, whom should be more aware of the current climate change and energy challenges and the higher access to internet might contribute to reducing energy consumption. In addition, the increased financing in the health system could contribute at energy savings and energy efficiency improvements.

For the study of the influencing factors of energy consumption, many models described by Equations (1) and (2) were tested and obtained.

$$PEC_{it} = \alpha_{it} + \sum \beta_{it} \times Economic_Var_{it} + \sum \gamma_{it} \times Energy_Var_{it} + \sum \lambda_{it} \times Socio - Eco_Var_{it} + \varepsilon_{1it} \quad (1)$$

$$FEC_{it} = \phi_{it} + \sum \eta_{it} \times Economic_Var_{it} + \sum \kappa_{it} \times Energy_Var_{it} + \sum \varphi_{it} \times Socio - Eco_Var_{it} + \varepsilon_{2it} \quad (2)$$

$\sum Economic_Var_{it}$ —Variables related to GDP, capital stock, internet users, gross fixed capital formation as a share of GDP, financial development, the external balance of goods and services, military expenditure, research and development expenditure in GDP. Each variable from this category tested in the panel model is attributed a different coefficient β_{it} or η_{it} , which offers information on the effect of the relationship with the endogenous variable and its impact. This means that the size and the sign of the impact of each variable in this category is different on primary energy consumption (PEC) and final energy consumption (FEC).

$\sum Energy_Var_{it}$ —Variables related to different types of energy consumption, energy mix, oil price and the share of net energy imports. To each variables from this category tested in the panel model, it is attributed a different coefficient- γ_{it} or κ_{it} , which offers information on the effect of the relationship with the endogenous variable and its impact. This means that the size and the sign of the impact of each variable in this category is different on PEC and FEC.

$\sum Socio - Eco_Var_{it}$ —Variables related to population, female population, degree of urbanization, female legislators, officials and managers, the proportion of women's mandates in national parliaments, the workforce, the share of the labour force that followed tertiary education in the total workforce, health expenditure in GDP, greenhouse gas emissions (GHG) emissions, share of agricultural area in total area, environmental taxes as a share of GDP and rental of natural resources as a share of GDP. To each variables from this category tested in the panel model, it is attributed a different coefficient; λ_{it} or φ_{it} , which offers information on the effect of the relationship with the endogenous variable and its impact. This means that the size and the sign of the impact of each variable in this category is different on PEC and FEC.

ε_{it} —Represents the error of each model [64];

i —Represents the geographic indication;

t —Represents the time considered in the analysis.

The energy mix has been tested by the energy consumption of fossil fuels (XFOS), renewable (XER) and nuclear energy (XEN) in total gross domestic energy consumption, according to several authors [54,59,65].

In addition, the independent variables were tested on both total and divided to the population and the results indicate insignificant differences. So, this research presents only the results which considered the total independent variables.

All the indicators used in the models present the state and the evolution of the society on a certain time frame. These have been introduced in the econometric models after fulfilling the hypotheses necessary for regressions validity. So, the data was tested for stationarity, the existence of a normal distribution, and multicollinearity between the variables used in the same model.

Data stationarity was tested for the variables of all models analysed by indicating the existence of the unit root at the panel and the individual series, i.e., the presence of autocorrelation between past data of the same variable [64], which should not appear in order to apply the regression model. According to the applied tests, most of the variables were not stationary at the first level, the stationarity being identified at their first difference, generally by considering a constant or a lack of trend and constant after the graph of the time series [18]. Also, natural logarithm was applied to the energy consumption, GHG, GDP accumulation of capital (K), population and workforce indicators for estimating the elasticity of coefficients of variables in regressions. Then the difference was applied in the case of non-static data [57], which leads to normalization of time series. This was the case of all variables considered in the models.

Further, the variables were considered for a model only if the collinearity coefficient was less than 0.5 and the causality between them was found present. The correlation matrix contributes to establishing regression models as it highlights the multicollinearity that does not have to be present between the regression variables [18].

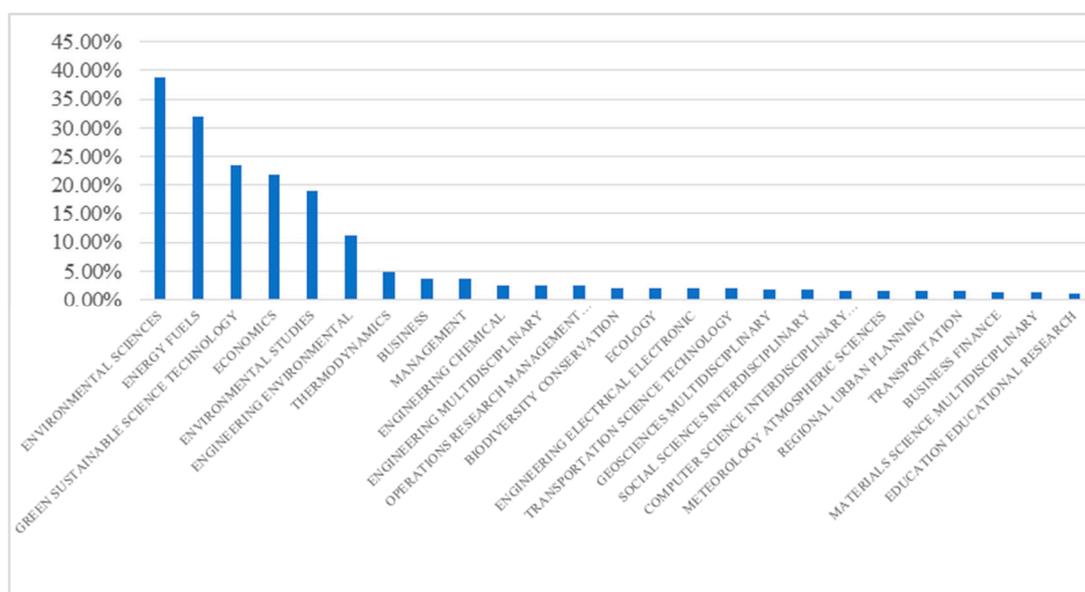
Moreover, the Granger test provided the existence of the causality between two variables, two by two, but there are a multitude of determinants of the analysed endogenous variables that act together within the holistic system. Therefore, those variables that appear to have no influence on the dependent variable may in fact cause changes in the endogenous variables. This can be highlighted by presenting the results of multiple regression analysis, which also highlights the sign of the changes made. So, the results of the causality tests were also considered in the construction of the models at the EU28 level during 1995–2014 [18]. Thus, it was found that there is a causal relationship of GHG and economic growth on energy consumption at EU28 level in the short and medium term, as demonstrated in previous studies by Kasman and Duman [17] for the EU12 and Saidi and Hammami [30] for 58 countries, of which EU15 can be observed. In addition, the economic and social determinants common to all two types of energy consumption analysed as endogenous variables are as follows: Capital accumulation, environmental taxes, oil prices, population, representatives in female leadership positions, labour force, and number of Internet users. In addition, percentage changes in both primary and final energy consumption are caused by past financial development, as is also the case of Saidi and Hammami [30] article, however, it does not capture the influence of capital accumulation. At the same time, trade openness, along with previous levels of natural resource depletion and agricultural surface, causes changes in primary energy consumption, like the outcome of Kasman and Duman [17], but no such evidence was found for the final energy consumption. Another interesting result is the causal influence of the urbanization change on the final energy consumption, which has not been econometrically demonstrated yet at EU28 level. Another important explanatory variable, RD-GDP, causes changes in the final energy consumption, a fact that is politically relevant by highlighting the importance of research in developing the technologies needed for energy sustainability. Finally, the past percentages of tertiary education workforce are generating changes in final and primary energy consumption, which highlights the importance of educating and informing employees about sustainability requirements and new green energy policies.

4. Results

4.1. Results of the Bibliometric Analysis

The bibliometric analysis is generated on 671 articles available on the Web of Science database, which resulted after using the terms “energy”, “emission*” and “economy” in the query and refining the results after the “relationship” filter word in the 1975–May 2019 time frame. This search allowed to keep only the results with a model included. One may see that there is an increased interest from research for this topic, as several authors try to expose possible models for determining the relationships between the three areas considering different influencing factors.

Considering the Web of Science categories of research, as presented in Figure 1, 38.75% of the articles are related to the environmental sciences area of interest, followed by energy fuels (31.89%), green sustainable science technology (23.55%), economics (21.76%) and environmental studies (18.93%). The other areas of interest have a lower percentage, 19 of the areas of interest have less than 5% of the articles found under the mentioned conditions. Following the previous mentioned facts, one may understand that there are several research areas interested in determining the relationship between the three components (energy consumption, emissions and economy), and they may be grouped either under the environmental studies/ecology umbrella, either under the socio-economic studies umbrella.

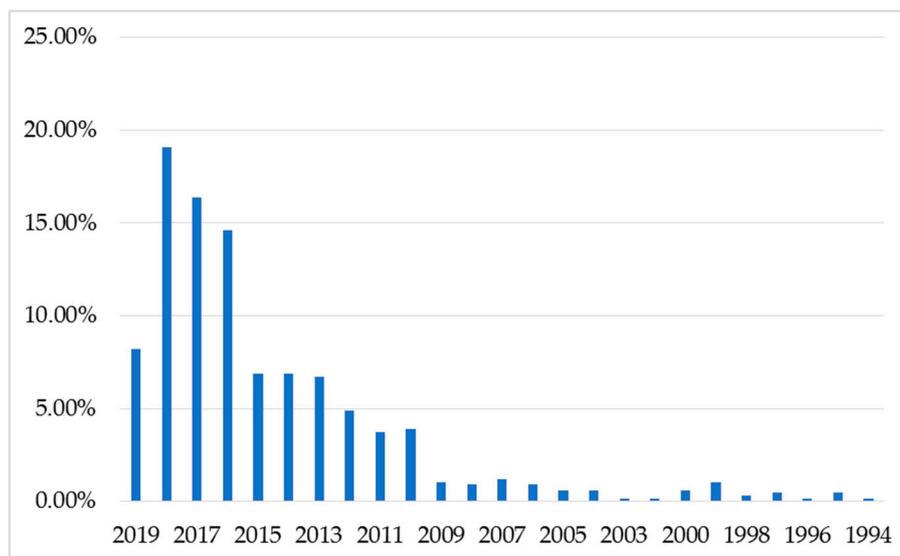


Source: Our own quantitative data processing of the 671 article abstracts downloaded from Web of Science.

Figure 1. Percentage of articles in the Web of Science research categories.

The interest in this topic has increased in recent years, as one may see in Figure 2. The first article appeared in 1994, and until 2010 the number of articles per year remained under 8, only 8.64% being published in this time period. In 2010 the number of articles reached 26, and it sky-rocketed in 2017 (110 papers) and 2018 (128 articles). In 2019, until May, there were already 55 articles published on this area of interest. The significant increase of interest in the area may come from the higher pressure posed by the current consumption pattern and the need to find better ways of living, as well as from the different options of renewable energy presented by the researchers.

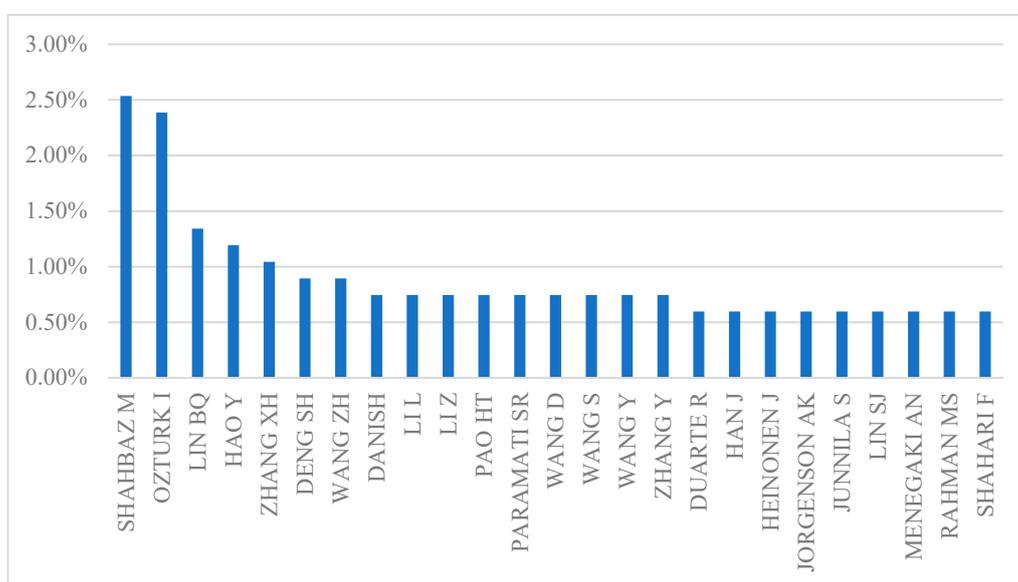
From the total number of papers, almost 74.5% (500) are journal articles, 17.75% (119) are conference proceeding papers, 9.25% (62) are reviews, while less than 2% are other types of papers, such as book chapters.



Source: Our own quantitative data processing of the 671 article abstracts downloaded from the Web of Science.

Figure 2. Publishing years.

The most prolific ten authors on this field, as shown by the analysis, have more than five articles written in this area of interest. In Figure 3, it can be seen that Shahbaz M has is on the top with, 17 articles (2.53%) written on the topic, followed by Ozturk I with 16 (2.39%) and Lin Bq with nine (1.34%) articles. It must be mentioned that all of the authors who published in this area of interest have at least four (0.60%) articles written on the topic, which can be understood as an offering field and a dynamic one, which needs to be constantly analysed.



Source: Our own quantitative data processing of the 671 article abstracts downloaded from the Web of Science.

Figure 3. Publishing authors.

The source countries for the articles written in this field come from The People’s Republic of China, where around 42.62% (286) of the articles have this source country. The following source country is the USA, with a dramatic difference of approximately 29%, as 12.97% (87) of the articles were written by authors of this country. The top three is completed by Turkey with 6.86% (46) of the articles being

On the map, the most used concepts in the analysed paper abstracts are gathered in three main groups, differentiated by colours. In red, there are several focal points: Emission, energy, policy, consumption, role, level, scenario and production (terms such as model, paper and analysis may come from the article description and are not relevant for the current analysis). One may say that the macro elements of the “energy system” are included in the red cluster, from the resources and production, to the consumption and the emissions. In blue, there are two types of terms, one related to possible producers of emissions, such as China or Beijing—with direct names and county, regions, city—as general geographical structures or industry, industrial structure—as economic sources of emissions. The second type is related to possible solutions of improvement, such as the following terms: Low carbon economy, change, development, efficiency, emission reduction or energy saving. In green, the group is formed mostly by the economic related concepts, such as: Economy, economic growth, energy consumption, growth, financial development or country.

It is important to mention that the term relationship is in the middle of the map and it connects all the focal point of the current research (energy, emission and economy), but also other important aspects that prove the right selection of papers for this analysis, such as: Model, variable, analysis or granger causality test.

4.2. Results of the Panel Data Models

In the proposed models, the determinants of energy consumption are estimated by using EU28-tested data panels for the period 1995–2014. The 17 developed models have been tested for the relevance of fixed effects, as well as to see if the random model is a better estimate than the fixed model. In this respect, the fixed effects test, as well as the Hausman test, was applied to both cross-sectional and period correlations, taking into account the null assumptions of each model presented in the methodology. The direction and magnitude of impacts of socio-economic and environmental determinants of primary and final energy consumption are presented and discussed in the following two sections [18].

4.2.1. Determinants of the Primary Energy Consumption

In order to identify the variables that may have an impact on the primary energy consumption, several variables were used, by investigating multiple international databases, which were presented in the materials and methods section. Along these, there could be also other indicators with various influences both as a sign and as a magnitude depending on the combinations considered in the multiple regression models. The results obtained from Equation (1) are highlighted in Table 4.

The regression results of estimating the percentage change in primary energy consumption as an endogenous variable in Table 4 indicates that there is a primary energy cost that EU countries have to assume. All independent variables, which registered a negative sign of the coefficients in Table 4, have a negative relationship with the endogenous variable, which can be translated as a positive effect on reducing the energy consumption and mitigating climate change. Contrary, the positive signs indicate a positive relationship with the endogenous variable, which can be translated as a negative effect on reducing the energy consumption, as the effect is one of growth.

Model 8 and model 10 suggest a linear negative impact of the change of economic growth (GDP) on the dependent variable, in the sense that the 1% augmentation of GDP determined an increase of PEC by 0.38% and 0.32% during 1995–2014. Although the relationship is positive, the effect is considered negative because one of the objectives of sustainability is saving energy through conservation and energy efficiency.

Table 4. Results of the multiple regressions regarding the percentage modification of primary energy consumption.

Dependent Variable: Percentage Change in Primary Energy Consumption (PEC)										
Variables	Model1	Model2	Model3	Model4	Model5	Model6	Model7	Model8	Model9	Model10
Constant	0.0229 (<i>p</i> = 0.1868)	−0.0028	−0.0005	−0.0061 **	−0.0058 *	−0.0043 (<i>p</i> = 0.178)	0.0021	−0.0160 ***	−0.0079 ***	−0.0077 ***
GDP	0.0521							0.3868 ***		0.3239 ***
GDP-2	0.0817		1.4464 **		2.1064 ***	1.29 *	0.8832 *	1.0191 (<i>p</i> = 0.176)	0.0944	
GHG	0.8139 ***						0.7537 ***			
RE	0.0025 *		−0.0098 ***		−0.0127 ***					−0.0098 ***
FFE		0.0083 ***				0.0014		0.0026 **		
NE				0.0066 ***			0.0080 ***		0.0053 ***	
EP	0.0077 *		0.0116 **		0.0813 **	0.0096 *	0.0141			0.0133 **
REL				−0.0026 ***		−0.0026 ***			−0.0023 ***	
NEL	0.004 ***		0.0026 ***		0.0025 ***					
K		0.0908 ***		0.1063 ***					0.1336 ***	
K-GDP			0.0032 ***			0.0042 ***				
EIMP				0.0007 (<i>p</i> = 0.161)	0.0001	−0.0012 **		−0.0010 *		
C-GDP	0.0002 ***	0.0002 **					0.0002 ***		0.0001 *	0.0002 **
SE-GDP										0.00009
EB-GDP					−0.0024 **					−0.0017 *
M-GDP						0.0147	0.0123 (<i>p</i> = 0.166)			−0.0003
RD-GDP		0.013						0.0279 (<i>p</i> = 0.177)		0.0586 ***
AA								−0.002	−0.0006	0.0025 *

Table 4. Cont.

Dependent Variable: Percentage Change in Primary Energy Consumption (PEC)										
Variables	Model1	Model2	Model3	Model4	Model5	Model6	Model7	Model8	Model9	Model10
NR-GDP		0.0074 *	0.0054 (<i>p</i> = 0.190)	0.0070 *				0.0075 (<i>p</i> = 0.100)		
ENVT							0.0053	−0.0071	−0.0102	
POP				0.5513 ***			0.5109 ***			
PD			0.0019 **		0.0016 *				0.0013 (<i>p</i> = 0.112)	
UPOP						0.0117 *		0.0157 **		
FPOP						−0.1020 **	0.0379	−0.1500 ***		
FM					0.0013 *		0.0008 *			
WP					0.0003				0.0010 (<i>p</i> = 0.179)	
WF		0.2841 ***			0.3126 ***					0.1934 *
TEDU						0.0005	0.0004		0.001	
H-GDP		−0.0113 **		−0.0120 **			−0.0066 *			
IU			0.0002	0.0008 *		0.0003				
Cross-sectional fixed effects	0.397	0.6305	0.5879	0.9574	0.3832	0.6306	0.5593	1.0405	0.3554	0.8196
Time fixed effects	1.8974 **	8.7024 ***	10.4632***	8.1307 ***	10.6465 ***	9.2658 ***	3.9447 ***	5.5346 ***	10.4968 ***	7.0418 ***
Hausman test: Random cross-sectional effects	no	no	no	no	no	no	no	no	no	no
Hausman test: Random time effects	23.3549 ***	10.0986 (<i>p</i> = 0.183)	20.6306 ***	23.6940 ***	39.8784 ***	59.9496 ***	58.0518 ***	36.8054 ***	43.1908 **	16.4772 *
R-squared	64.26%	20.43%	42.61%	46.43%	45.54%	40.01%	78.78%	34.82%	46.39%	49.31%
F-statistic	32.80 ***	14.41 ***	13.73 ***	13.53 ***	12.65 ***	10.48 ***	46.22 ***	8.32 ***	11.58 ***	11.60 ***
Durbin–Watson	3.02	2.14	2.22	2.06	2.41	2.28	2.75	2.16	2.33	2.31

Note: Statistical significance, *p*-value, * 10%, ** 5% or *** 1%. Source: [18].

In contrast to the study of Çoban and Topcu [16], which identifies mixed relations between economic growth and energy use at EU27 level during 1990–2011, the results of the current economic growth impact on primary energy consumption in the EU28 during 1995–2014 suggest only linear relationships of intensification of the endogenous variable. However, if we consider the separate findings of Çoban and Topcu [16] in the case of the old member countries and the case of the new ones, then the results are similar to this study. Nevertheless, the magnitude of the change induced by economic growth cannot be compared with the study by Çoban and Topcu [16], as they reported the variables to the number of inhabitants achieving increases in energy use per inhabitant of 0.03–0.04% over a different period. In addition, the results are similar to the study by Saidi and Hammami [30], which notes the increase in energy consumption caused by GDP per capita. Thus, correlations with specialized researches in the case of the economic growth of the EU28 on primary energy consumption suggest that studying aggregates in a variable generates a clear, positive relationship with a high negative impact, increasing consumption as a state develops on the economic level.

The relationship between GDP and PEC suggest that, for the time being, the EU28 still needs to stimulate the decoupling of economic development from energy consumption. As other studies [10,24–26] demonstrate, this decoupling would not affect the further development of the member states. In addition, this lack of decoupling, which will intensify energy consumption, can be attributed to the new EU states (EU13), which still do not have the same level of economic development as the EU15 and therefore energy consumption will not diminish if economic growth will improve in the new member states, i.e., the EU13, including Romania, without strong active measures to change consumer patterns and achieve energy saving. However, in order to substantiate this statement, as Çoban and Topcu [16] realize, a future study could retest the models presented in Table 4 at EU15 and EU13 levels.

Moreover, the increase of energy consumption stimulates the growth of greenhouse gas emissions, which further contribute to climate change [66]. In this context, the aim of the EU decision makers could be to stimulate and evaluate the social welfare through other indicator than GDP. Further, one focus of the developed countries could be the implementation of green technologies, which are more energy efficient and register energy savings. In terms of developing countries, these could aim to increase their GDP by also adopting environmental and social-friendly practices, as these are viable in the context of the fast climate change.

At the same time, the change in GHG emissions, which growth in the analysed countries by 1%, has led to an increase of the primary energy consumption (PEC) by 0.75–0.80% in the period 1995–2014. This fact is given by the positive relationship between the influences of GHG emissions on primary energy consumption, which is presented in Table 4 through the + sign of the coefficients. This negative effect of stimulating energy consumption due to increased pollution, which supports the research hypothesis, is similar to the findings of Saidi and Hammami [30], who introduce part of the EU countries into their analysed group. Similarly, Wang et al. [11] show GHG emissions as a determinant of increasing energy consumption internationally. While the relationship between GHG emissions and energy consumption seems to be a bidirectional one, as shown in our analysis and that of [66], the decision makers should focus on reducing energy consumption through various measures, such as financial incentives or tax reductions on sustainable practices, promotion of the importance of both energy savings for the consumer sector and energy efficiency in all sectors of economy, changing the behaviour of consumers by applying punitive measures for those who do not comply with the regulations in the field, and so on.

Similarly, the energy mix from fossil fuels (FFE) and nuclear energy (NE) generated a 1% increase in the change in primary energy consumption by 0.008% and 0.006%. This result, in the case of the share of fossil fuel consumption, may be caused by their still intensive use. In the case of the share of renewable energy consumption (RE) it is observed that the effect is contrary to FFE and NE, i.e., positive, of diminishing the dependent variable, PEC, by 0.009–0.012%. The impact meaning and magnitude are similar in the case of the change in green electricity production (REL) and that from

nuclear sources (NEL). Thus, the benefit of reducing the primary energy consumption generated by the use of renewable energies is captured. This means that the decision makers should focus on developing public policies which aim at stimulating the production and use of renewable energy, bearing in mind as well the requirement of energy savings.

Contrary to the research hypothesis, the positive sign the oil price change (EP) in relation to the change in primary energy consumption shows that the 1% increase of oil price produced a growth of 0.007–0.081% of PEC during 1995–2014. Subsidizing the fossil fuel industry can explain this effect as well as the price of these non-renewable resources that do not include the negative externalities of the environment and human health. This is contrary to the findings of Çoban and Topcu [16], who identify a negative relationship in the EU27, between 1990 and 2011, a positive effect of lowering the use of energy per capita based on rising oil prices. Indeed, the differences in the analysis are related to the methodological approach, the data used, the time period considered and the target group. Thus, in the future, there is a need for reiterating this relationship for the EU28 and, again, its separate analysis for the EU15 and the EU13, with a view to homogenizing the groups.

The effect of changing the share of net energy imports as a share of the total energy used by a country (EIMP) on the dependent variable seems mixed, although the statistical significance only appears for the positive effect generated by the models 6 and 8. The positive effect of decreasing the consumption change of primary energy by increasing the share of net imports in energy consumption may be due to the promotion of the need for energy independence as well as the additional economic efforts of a country to source energy from imports, especially when the country owns the energy resources needed for energy security.

In order to deepen the impacts of the economic system indicators, other variables were tested. Thus, the changes in capital stock (K) and the change in gross capital formation as a share of GDP (K-GDP) lead to a negative effect on the change in primary energy consumption (PEC), in the sense that the increase of these indicators by 1%, it generates increases of PEC with 0.09–0.13% and 0.003–0.004%. This result is similar to the findings of Saidi and Hammami [30], who identify an increase in the use of energy per capita at the level of some 15 European countries due to capital stocks, but the relationship of this study is insignificant. Thus, the results in Table 4 suppress the statistical significance required for their validation. A lower negative effect also occurs in cases of change in financial development (C-GDP) and change in commercial opening (SE-GDP). Again, the impact of financial development on the rise in primary energy consumption is similar to that of Saidi and Hammami [30]. Also, the impacts of these two variables illustrated by the results are similar to the findings of Azam et al. [53]. Another indicator that captures commercial opening, but which has a positive effect on diminishing the change in primary energy consumption is the change in the external balance of goods and services as a share of GDP (EB-GDP), but its impact is very low, of –0.002%.

As with the impact on the change in the share of renewable energies in consumption, the change in the share of military expenditures in GDP (M-GDP) is not statistically significant on the change of the primary energy consumption, their correlation being inconclusive due to the mixed results recorded. Therefore, the research hypothesis that M-GDP growth would generate the augmentation of the primary energy consumption is not confirmed, producing a negative effect on the holistic system.

At the same time, contrary to the research hypothesis that R & D expenditure share (RD-GDP) in GDP generates a positive effect on the change in primary energy consumption in order to stimulate energy saving, the effect of this relationship is negative. A 1% increase in RD-GDP stimulated the endogenous variable enhancement by 0.058%. This surprising result indicates the failure of EU energy saving by 2014 and the possibility of a concave relationship between RD-GDP and PEC, as in the case of Kuznets. In addition, the same effect is observed with the change in the number of internet users (IU), whose 1% improvement causes a very small increase in the change in primary energy consumption by 0.0008%. However, the development of internet access implies the development of residential communications, indicating a better living and, implicitly, increasing energy consumption based on the use of electrical equipment and devices, confirming the results of Wang et al. [43].

The indicators considered for environmental assessment are either statistically insignificant, the case of changes in environmental taxes (ENVT), or they have opposite effects, the cases of changes in the weight of the agricultural area (AA) and the depletion of natural resources (NR-GDP). Although the research hypothesis implied a positive effect of ENVT on the change in primary energy consumption, the mixed and inconclusive results do not allow validation, nor its rejection. Instead, the negative impact of NR-GDP on PEC confirms the research hypothesis that energy consumption is growing as natural resources grow in exploitation, while the positive effect of AA on the endogenous variable rejects the hypothesis of research. Thus, as the change in the share of the agricultural area increases, the change in primary energy consumption decreases by 0.002%. This is surprising because the intensification of agricultural activities generates the increase in the use of energy. However, the development of green agricultural technologies can explain the situation identified at EU28 level.

Most social variables confirm the hypothesis of research. The most important social determinant, with a negative effect on the socio-ecological complex is the population. With a 1% increase in its change (POP), the primary energy consumption increased by 0.5%. This result is similar to that identified by Saidi & Hammami [30] generally applied for the estimation of energy use and shows that the population has a much more significant impact in the countries of Latin America than Europe. The same negative effect, but at a lower level, is also found for population density. In this respect, an increase of the population density (PD) by 1% determined an increase of the dependent variable by 0.001%. Also, the change in the degree of urbanization (UPOP) influenced only by 0.01% the primary energy consumption. This positive relationship, which sees a negative effect on the holistic system, is also indicated by Azam et al. [53] and Wang et al. [11], but for another geographic area, another period, and using another methodological approach, which of course has generated other magnitudes in the impact of urbanization on the increase in energy consumption. Obviously, agglomerations of the population intensify energy consumption, so the negative effect in this case proves the research hypothesis. Another significant negative impact is due to the change in the workforce (WF), whose 1% increase caused the increase in primary energy consumption by around 0.19% and 0.31%, depending on the factors of influence considered in the analysis.

Surprisingly, the increase in primary energy consumption is due to the rise of female decision makers (FM) as well as due to the increase in the share of educated workforce at least at tertiary level (TEDU). However, TEDU is statistically insignificant. Thus, it seems that the negative effects of these two indicators on the state of the holistic system must be carefully investigated in the future using other methodological approaches. As to the proportion of women's mandates in national parliaments, the effect is insignificant in statistical terms, but the meaning seems to indicate a negative effect posed by the positive correlation, i.e., a 1% increase in the proportion of mandates held by women in national parliaments (WP) led to an increase in primary energy consumption. The opposite, i.e., positive status, the effects of decreasing primary energy consumption by 0.10–0.15% and 0.01%, respectively, occurred due to the 1% increase in the share of the female population in the total population (FPOP), respectively the change in the share of health expenditure in GDP (H-GDP).

Most of the models are not auto correlated because Durbin–Watson is close to the value of two. They are also statistically relevant, and the amount of information recovered ranges from 20% to 78%.

4.2.2. Determinants of Final Energy Consumption

Another analysis was carried out on final energy consumption, with the aim of identifying variables that have a positive or negative influence on it. As in the previous cases, both economic variables and socio-ecological indicators of the holistic system were considered to best capture the relationships within it, the role of the energy sector and the evaluation of past policies. The results of the analysis based on Equation (2) are presented in Table 5.

Table 5. Cont.

Dependent Variable: Percentage Change in Final Energy Consumption (FEC)							
Variables	Model1	Model2	Model3	Model4	Model5	Model6	Model7
UPOP				−0.0100			
WP		0.0009				0.0004	0.0004
WF			0.3461 ***	0.2909 ***			0.2355 **
TEDU		0.0012 *		0.0008		0.0001	
H-GDP			−0.0093 ($p = 0.107$)			−0.0101 *	
IU						0.0001	
Cross-sectional fixed effects	0.3326	0.6658	0.6372	0.3382	0.4572	0.1771	0.3782
Time fixed effects	3.0482 ***	10.63 ***	7.592 ***	11.8825 ***	10.5902 ***	4.3158 ***	4.2123 ***
Hausman test: Random cross-sectional effects	no	no	no	no	no	no	No
Hausman test: Random time effects	18.9495 **	29.0991 ***	19.0455 *	12.3588	7.9126	13.5853 ($p = 0.145$)	62.67666 ***
R-squared	65.53%	48.74%	55.00%	47.59%	15.19%	43.86%	51.97%
F-statistic	23.3540 ***	14.9225 ***	12.8999 ***	12.6450 ***	6.6479 ***	31.8689 ***	19.3905 ***
Durbin–Watson	2.41	2.35	2.44	2.34	2.1	2.6	2.06

Note: Statistical significance, p -value, * 10%, ** 5% or *** 1%. Source: [18].

The results of the final energy consumption determinants show both similarities and significant differences compared to those related to primary energy consumption.

In the case of GDP influences, the same linear trend of increasing the final energy consumption (FEC) was observed, but with the negative effect of 0.45–0.49%, which is approximately 10% higher than the primary energy consumption (PEC) case. In addition, ignoring statistical insignificance, model 3 even shows the hyperbola relationship between FEC and GDP. Similar effects to PEC occurred in the case of GHG emissions change (GHG), which 1% increases stimulated FEC growth by 0.53–0.74%, with a lower negative effect on PEC. This was somewhat expected, because the final energy consumption depends on the primary energy consumption.

In addition, the energy mix generated impact on the final energy consumption changes similar to those related to the change in primary energy consumption, except for the influence of the change in the share of nuclear energy consumption (NE), which generated statistically significant positive effect. Thus, the decrease of final energy consumption by 0.001% was caused by a 1% increase in NE. However, in the 7th model from Table 5, there is also a negative effect, statistically insignificant, which shows the necessity of further research. At the same time, both changes in fossil fuel consumption (FFE) as well as changes in the share of renewable energy in consumption (RE) have the same effects as in the primary energy determinants analysis: the negative effect of FFE caused the increase in FEC (0.006–0.007%) and the positive effect of RE generated decreases of FEC (−0.002–0.003%). In this case, the negative effect of the oil price change (EP) on the change in final energy consumption (FEC) contradicts the research hypothesis, according to which high oil prices cause a reduction in energy consumption. In this respect, the decrease of FEC by 0.019–0.069% occurred due to the increase in oil prices by 1%. This result can be explained by the diversification of the energy mix and the high possibilities of replacing oil with other energy sources.

Comparing the results in Table 4 with those in Table 5, it was found that there were identical results on the impact of some indicators on both primary and final energy consumption. These determinants with identical effects, previously interpreted, are as follows: Changes in net energy import (EIMP), changes in gross fixed capital formation (K-GDP), change in external balance (EB-GDP) and changes in health expenditure (H-GDP). At the same time, similar influences from capital stock changes (D_LOG_K) and commercial openness (SE-GDP) were observed. In the first case, the 1% increase in capital stock caused an increase of 0.03–0.05% in final energy consumption, the value being about half the value for primary energy consumption. In the second case, although a positive mathematical relationship was observed between SE-GDP and FEC, it generates a negative effect on the evolution of final energy consumption, but is not statistically significant.

What is interesting is the adverse impact of financial development on final energy consumption compared to primary energy consumption. Thus, the change in final energy consumption diminished with very low values of 0.0003–0.0004% amid a 1% improvement in financial development, thus indicating a positive effect on the trend of the endogenous variable at EU level during 1995–2014. This time, the research hypothesis was confirmed.

Contrary to the influence of primary energy consumption and the research hypothesis, the increase in the share of military expenditures in GDP (M-GDP) stimulated the reduction of the final energy consumption change by 0.01%, similar to the result recorded in the case of testing the regressions on GHG emissions. From the author's knowledge, there is no evidence of this relationship, but only the study by Jorgenson and Clark [56], which supports the increase of the ecological footprint by this indicator, i.e., the intensification of national consumption. An opposite effect on FEC, which once again rejects the research hypothesis, is caused by a change in the share of R & D expenditure, since improving it by 1% causes increases in final energy consumption by 0.04–0.08%.

Further, a 1% increase in the change of the share of the agricultural area (AA) led to an increase of the final energy consumption change by 0.003%, contrary to the influence on the primary energy consumption, but confirming the research hypothesis that the increase in agricultural area determines increased energy consumption as a result of agricultural activities. At the same time, a 1% increase of

the share of environmental taxes in GDP (ENVT) generated final energy savings between 0.01% and 0.02%, which confirms the research hypothesis.

Last but not least, the influence of the social variables on the final consumption of energy, which are similar to the effects of the primary energy consumption, were tested, except for the change in the population density, which, this time, inversely influences the endogenous variable, inducing a decrease in the final energy consumption with 0.0015%, contrary to the research hypothesis. However, strong impacts were identified in population change (POP) and labour change (WF). Thus, a population increase of 1% caused the final energy consumption to increase by 0.45%, while the increase of the labour force change by 1% caused the increase of the final energy consumption change by 0.23–0.34%. Another increase in the change in final energy consumption was caused by the increase in the share of the labour force with tertiary education in the total population (TEDU), the increase being about 0.001%. Although the research hypothesis is rejected, energy consumption has increased in this case, probably because of higher social welfare than other social categories, which induces the use of more energy-consuming equipment and technologies. The last tested variables do not present statistically significant values of the coefficients, but they can be interpreted in terms of meaning and influence they could have on final energy consumption. Thus, the increase of the proportion of women's mandates in national parliaments (WP) and the growth of Internet users (IU) appear to have increased final energy consumption. However, the existence of low values is noted, therefore, even if the effect would have been statistically relevant, the influence would have been almost insignificant.

Finally, the models estimated in Table 5 are statistically relevant according to the F Test. In terms of the Durbin–Watson test, which does not indicate autocorrelation for values close to two, the analysed models do not exhibit autocorrelation or, if present, cannot be determined by the Eviews software. The amount of information recovered is between 15% and 65%.

5. Discussion

Some studies [17] confirm the existence of a concave relationship between the economic development and the degradation of the natural environment, according to Kuznets' curve evolution, also a positive relationship is proven by other studies [22,23], while others [32,61] invalidate this relationship. Similarly, there are studies on the social dimension [3,36,60], which show that improving the conditions of the natural environment contributes directly to the improvement of social and institutional performance, components that are part of the social system of society. At the same time, the causality between economic development and social performance is shown, but the sign of the relationship is not conclusive [61]. Of course, in all these records, the role of the energy sector is undoubtedly important in mitigating climate change.

One of the purposes of the research was to analyse the factors of influence of energy consumption at EU28 level between 1995 and 2014. Several types of energy consumption were considered: The primary energy consumption and the final energy consumption. The models generated relevant information for both national and European policy makers as well as for the scientific literature on energy.

Table 6 summarizes the results of the analysis of the determinants of the endogenous variables considered.

First, the determinants with a strongly significant impact on the evolution of primary energy consumption are as follows: GHG emissions, GDP, size of human population and labour, capital accumulations and human feminine population. These strong influence factors have shown a positive relationship with primary energy consumption, with the exception of the human feminine population that has a negative relationship with the endogenous variable, which means that in the case of the EU28 the increase in the female population weight leads to a decrease of the energy consumption, thus stimulating the improvement of the state of the holistic system.

Table 6. Summary of the energy consumption determinants in EU 28, 1995–2014.

Independent Variables	Dependent Variables	
	PEC	FEC
GHG	+	+
GDP	+	+
GDP-2	+	+
FFE	+	+
RE	–	–
NE	+	–
EP	+	+
REL	–	+
NEL	+	
K	+	+
K-GDP	+	+
EIMP	≈	–
C-GDP	+	–
SE-GDP	!!	!!
EB-GDP	–	–
M-GDP	!!	–
RD-GDP	+	+
IU	+	!!
AA	≈	+
ENVT	!!	–
NR-GDP	+	
POP	+	+
PD	+	+
UPOP	+	!!
FPOP	–	
FM	+	
WP	!!	!!
WF	+	+
TEDU	!!	+
H-GDP	–	–

Note: Statistically significant relationship between endogenous and exogenous are denoted as follows: Positive + or negative –; ≈ Inconclusive relationship; !! Statistical insignificance. Source: [18].

In addition to the factors with a strong impact on the evolution of primary energy consumption, other determinants have also been analysed which have a very low influence on the endogenous variable. The latter recorded a positive relationship with the consumption of fossil fuels and nuclear energy, the oil price, the financial development, the research and development expenditures, the depletion of natural resources, the degree of urbanization, the population density, female decision makers and the number of Internet users.

By considering the negative impact of these factors on energy consumption, in the sense that it stimulates its increase, the policies should integrate sustainable principles and objectives of reducing them while increasing the social welfare. For example, while [59] indicate positive influence of financial development on reducing environmental impact, our results suggest an intensification of the energy consumption at EU level. In this case, as [59] states, financial developed countries benefit of innovative technologies and financial networks, which on long term stimulate diminution of environmental degradation. Although, initially, energy consumption and other use of resources could increase, the investments in green technologies are one of the best options for tackling climate change on long term. At the same time, being consistent with the findings of [43], the energy price rises seem to slowly intensify the energy consumption, which means that increasing the oil prices are not necessarily reducing the environmental impact. However, maybe aiming to stimulate the green initiative are more effective ways of tackling climate change. Further, the urbanization degree should be diminished by developing the sectors of health, education and services in rural area, as well as creating fast

linked infrastructure with the urban and peri-urban areas. In another example, the number of internet users would most likely increase in the future; however, technological development should focus on improving energy efficiency and energy use in production, transportation and consumption of these equipment and tools. In addition, although the proportion of women's mandates in national parliaments is a statistically insignificant determinant of energy consumption, its positive sign, along with that of women decision makers, indicate small intensification of energy consumption. While [59] found out that both the gender and the politic involvement of women influence the energy policies voting, the main influencing factor being the party affiliation, it seems like changing the views of the politic groups towards more green initiatives is more important.

In the same time, it was registered a negative relationship between primary energy consumption and the external balance of goods and services, the consumption of renewable energies and the health care expenditures, emphasizing the stimulation of the reduction in energy consumption. In this case, a policy measure should give, for example, tax reduction or other financial stimulus for reducing the energy consumption on all levels, as the traditional economic models of development and those based on consumption are not sustainable and intensify climate change. So, the developing countries should focus on not applying the pathways of developed countries, as Earth is already overstressed.

Then, a slightly different situation has been demonstrated in the impact of the final energy consumption determinants, which are statistically significant and more congenial in relation to the primary energy consumption factors. Again, the determinants with a strong statistically significant impact on the evolution of final energy consumption are as follows: GHG emissions, GDP, human population and labour, oil prices, R & D expenditure, capital accumulations and environmental taxes. Of these, with the exception of environmental taxes, all determinants had a positive relationship with final energy consumption, which means that in the case of the EU28 most of the high impact factors cause the intensification of the final energy consumption, which led, as a whole, the worsening of the state of the holistic system. It seems like policies which increase the environmental taxes stimulate the reduction of energy and, further, the climate change mitigation.

For assessing the macroeconomic perspective, it is also important to focus at microeconomic level, mainly at the factors that affect the decision to be friendly environmental and to invest in proper equipment. One of the factors that stimulate the green investments seems to be the length of the firm-bank relationship [67]. Other characteristics that encourage the green investment are related with the size, the age, the profitability and the innovative feature of the entity. It seems that more of these encourage entities to have a higher probability for investing in environmentally friendly equipment [67]. The problem regarding this type of information is that data on individual European EU firms are rare and incomplete and so, further studies should focus on it. The studies should look at the process of transforming micro-data into macro level observations in order to provide reliable information (for example R & D seems to encourage green equipment development, so smaller consumption of energy, while at macro level, the R & D expenditure from GDP seems to increase both the primary and the final consumption of energy). In Italy, facilitating the financing in green investment could create a win-win relationship for the environmental protection and it could provide long term values in features related with innovations, job opportunities or other social incentives [68]. On the other hand, uncertainty about the government policies, short term perspective of financial instruments and the lack of financial tailored to small-scale investment needs mitigates the effect of green financing opportunities. At the macroeconomic level, the growth of the economy has the highest net gain from a system where the stock market, mainly market capitalization of listed domestic entities, renewable energy-measured by shares of renewable energy in total final energy consumption-and non-hydro renewable electricity net generation, foreign direct investment inflows in GDP, domestic credit provided by financial sector in GDP, the Brent oil spot price and total greenhouse gas emissions are included [69]. Moreover, among the net determinants of the share of renewable energy are the credit market and the stock market. In China, fluctuations on oil prices also influence the energy structure. Considering the importance of oil

prices' fluctuations, options could be used to reduce the volatility of it and to quantify the benefit of using an active strategic reverse for volatility's mitigation [70].

In addition to the factors with a strong impact on the evolution of final energy consumption, other determinants have also been analysed which have a very low influence on the endogenous variable. Of these, fossil fuel consumption, agricultural land change, population density and tertiary education have led to increased final energy consumption, while renewable energy, nuclear power consumption, financial openness, net energy imports, the balance of external goods and services, military spending, and healthcare spending have led to a decline in final energy consumption. Future studies should also be developed to retest the impact of urbanization, commercial openness, internet users and women's influence in national parliaments on the evolution of final energy consumption at EU28 level as research has not produced conclusive findings in these cases.

Moreover, some variables registered statistical insignificance in relation with one type of energy consumption, such as military expenditures, internet users, environmental taxes, urbanisation and the tertiary education, as well as with the both types of endogenous variables analysed, such as trade openness and women in leading position. Although the military expenditure and environmental taxes stimulated the diminution of the finale energy consumption at EU level during 1995–2014, in terms of its correlation with primary energy consumption, it seems like statistical insignificance and mixed results are recorded. While the number of internet users, respectively the people with tertiary education, seems to increase the PEC, respectively the FEC, their effect on FEC and PEC is statistically insignificant, but with the same positive sign. These results are interesting as they indicate a higher use of energy when increasing the technological and the educational levels. Contrarily, while the increase of the urban population seems to increase the PEC, its effect on FEC is statistically insignificant, but with a negative sign, which means that the increase of urban population generated a diminution of the final energy consumption. This mixed result could be explained by the fact that, in the urban areas, the accommodations are smaller, being more apartments, which might consume less energy while the houses on rural areas could consume more energy. Statistically insignificant and with low impact, the trade openness seems to increase both types of energy consumption, based on the positive sign of its coefficients, such as in the models 1, 3 and 10. Similarly, the women in leading position seem to increase the energy consumption at the EU level, although some studies [71] show that their involvement seems to bring more environmental-friendly practices. Regarding the analysis conducted, it has been noticed that the combinations of factors influence differently the magnitude and sometimes the direction of the impacts of the determinants analysed on the endogenous variables and thus there is a methodological limitation of the research given that the multiple regressions do not allow the introduction of all available variables to evaluate the performance of the holistic system in a single model, because their effects would cancel each other out because of the lack of independence. However, the validity and diversity of results remains equally important to substantiate the need to improve both integrated and environmental energy policies. Nevertheless, it is proposed to carry out further analyses to apply new mathematical models based on complexity, such as those proposed by Marczyk [72] in the field of energy, as they allow the cumulative consideration of all available variables of a complex system, so such as the energy sector.

6. Conclusions

The relationship between economic, social and environmental factors, as a holistic system, and the consumption of energy (both primary and final) poses great interest for researchers around the world, the Chinese and Turkish researchers proving a remarkable amount of work placed in this field, but also for the authorities since reducing the non-renewable energy consumption is one of the UN sustainable development goals [12]. In addition, the scientific publication in this field has increased in the past years; the more the effects of climate change are becoming more obvious.

The panel models were conducted at EU level during 1995–2014 to estimate the determinants and their impact on both primary and final energy consumption. On one hand, it seems like the energy

consumption is stimulated by increasing the GHG emissions, GDP, the use of fossil fuel sources, the oil price, the capital stock, research and development expenditures, agricultural area, natural resource depletion, the population and its density, as well as the labour force. On other hand, it seems like the energy consumption is diminished by increasing health expenditures, the female population, the external balance of goods and services, environmental taxes, as well as renewable energies. Thus, the decision makers on both a regional and a country level should focus on these results for introducing into the public policies the reduction of the determinants which increase the energy consumption for climate change mitigation by using punitive measures, while promoting the sustainable practices for better understanding of the impact at both individual and society levels.

Most of the models proposed in this study include a wider set of variables from those present in the literature, some of which have not been tested so far. Thus, this research is important because it indicated many historical trends of the components of the social, economic and environmental dimensions, which must be considered in future sustainable energy policies as well as in setting new targets and collaboration in the integrated energy-climate field. In the future, it is proposed to continue the research by studying the variables at each state level together with integration of the national energy policies. In conclusion, the study supports decision-makers in evaluating energy policies in the context of sustainability requirements by providing analyses of the determinants of energy consumption.

Author Contributions: The authors worked together for this research, but, per structure, conceptualization A.Z.; methodology, software validation and resources, A.Z., L.B. and M.C.D.; formal analysis, A.Z., C.I. and M.C.D.; writing—original draft preparation, and writing—review and editing, A.Z., M.C.D., L.B. and G.-R.L.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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