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Does Economic Structure Differentiate the Achievements towards Energy SDG in the EU?

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Abstract: Energy sustainability constitutes an important goal for development, as declared at the global and the European levels. Some conditions decisive for energy performance, as suggested by the Environmental Kuznets Curve (EKC) hypothesis, may be specified by the sectoral structure of production, as industries vary in the intensity of energy consumption. Nevertheless, sustainability is not automatically induced along with economic development and it is important to identify its determinants. The aim of the study is to empirically verify whether the sectoral structure of an economy differentiates energy sustainability within 28 European Union member states (the EU-28). To fulfil the task, a static approach was adopted and such taxonomic methods as the Ward agglomeration method and linear ordering based on the Hellwig synthetic measure were used. The hypothesis concerning the essential role of structural features in energy achievements was verified by a one-way analysis of variance. Our results do not confirm the decisive role of economic structure in energy performance for the EU-28 states; however, they suggest some complex relationships. The interference between energy performance and sectoral structure mostly concerned primary and final energy consumptions and energy poverty, as well as the shares of agriculture, industry, traditional services and finance in total production. The findings reveal a need for further research into the potential interlinkages between different dimensions of sustainable development (SD).

Keywords: sustainable development; energy; the SDG 7; sectoral structure of production; European Union

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1. Introduction

Sustainable development (SD) is a central issue in the public debate led by scientists, politicians, activists and many others, since the way in which the development process occurs has an influence on all spheres of human existence. SD is commonly defined as in the Brundtland report [1,2] (p. 20) as "development which meets the needs of the current generations without compromising the ability of future generations to meet their own needs". It assumes that human socio-economic needs can be met in harmony with environmental issues [3] and that society's productive base per capita does not decline over time [4].

The importance of achieving SD is perceived at a global level, which is reflected by numerous political declarations, of which the UN's "2030 Agenda for Sustainable Development" [2,5,6] is the most current in expressing the international pursuit of SD. At the European Union level, SD also comprises a central policy objective. It has been enshrined in its treaties since 1997, including its ascending strategies of development and policy initiatives (such as the "Europe 2020 strategy" (2010) [7], the European Commission's Communication "Next steps for a sustainable European future: European action for sustainability" (2016) [8] and "European Green Deal" (2019) [9]) [2].

SD is usually specified by its three dimensions: economic, social and environmental, with a strong interdependence [10,11] and, thus, the 2030 Agenda presents a complex and holistic attitude, one which has been adopted at the EU level as well. This is expressed by the 17 Sustainable Development Goals (SDGs), with progress towards them being regularly monitored to maintain balance between the social, economic, environmental and, additionally, institutional dimensions of sustainability. All the spheres are internally complex, which results in difficulties in both their description and assessment as well as the possible trade-offs or synergies between the SD dimensions, together making the issue even more complicated. Some efforts to identify the interlinkages between the SDGs have been already taken by researchers and institutions (e.g., European Commission's Joint Research Centre (JRC) [12], International Council for Science [13] and Interlinkages Working Group of the IAEG-SDGs [14]) [2]. Nevertheless, there is still a need to investigate the potential interlinkages between different aspects of the process of development and not just limited to those specified in the SDGs.

This study forms part of wide-ranging research into the relationships between different aspects of SD; however, it considers the relatively neglected issue of the structural foundation of the achievements in terms of the sectoral/branch-level distribution of production, which is beyond the SDGs' scope. The economic structure is understood here as proportions between contribution of each sector into total production and is expressed by sectoral shares in gross value added (GVA). This paper focuses on the importance of the structural features of economic production for the energy goals of SD as an issue appealing to the modern actions declared by the EU.

The SDG 7 pays special attention to energy use and production as an essential aspect of the environmental dimension of SD, especially considering climate change. The goal is specified as "Ensure access to affordable, reliable, sustainable and modern energy for all" and efforts towards achieving it cover improving energy efficiency and productivity, reducing energy consumption (in all economic sectors and households), increasing the share of renewable energy production, ensuring the security of energy supply and limiting energy poverty [2]. In the EU context the achievements are monitored based on the EU SDG indicator set prepared by Eurostat [15]. As reflected in the Europe 2030 climate and energy framework, the EU aimed to improve energy efficiency by 20% by 2020 [5] and by at least 32.5% by 2030 according to the revised Energy Efficiency Directive [16]. In the Europe 2020 Strategy [5], the target for the share of renewable energy sources in final energy consumption was 20% by 2020 and at least 32% by 2030, according to the revised Renewable Energy Directive [17]. The Energy Union Package [18] set the goal of the EU becoming a world leader in renewable energy sources [2]. The energy results appear to differ between EU member states and, thus, identifying the sources of such differences is an important task from the theoretical and application points of view. This study examines the issue in reference to the structural characteristics of production.

The theoretical background for setting the structural features as a determinant of energy usage and production is derived from the widely discussed environmental Kuznets curve (EKC) [19–31]. Although it is still not plausible whether a broad relationship exists between economic development and environmental quality, as the EKC suggests [24] and while many scientists perceive the EKC as a statistical artefact [26] or consider it to offer little if any empirical support for its existence [28], then the concept remains of vivid interest. Generally, it suggests that with increasing income per capita the indicators of environmental degradation first rise and then fall [19]. The main explanation for this lies in structural changes "from a clean agrarian economy to a polluting industrial economy and then to a clean service economy" [22,29]. The logic behind the EKC is that if there were no change in the structure or technology of the economy, then pure growth on the scale of the economy would result in a proportional growth in pollution and other environmental impacts [23]. This relates to the fact that each industry is specified by a different environmental effect in terms of pollution emission, energy intensity and input mix. At higher levels of development, such as those that apply to the EU member states, structural change towards information-intensive industries and services is expected to result in a gradual decline in environmental degradation [19,30]. Verification of the thesis tends to be ambiguous. Some researchers claim that although structural changes (on the input and output sides) may be important in some countries at certain times for modifying the "gross scale effect", their average contribution seems less important quantitatively than "time-related effects" [19]. For developed countries in particular, structural change is often less important than technological innovation across sectors [22]. Despite the controversies about the role of structural patterns for environmental quality in advanced economies, it is still an important task to empirically verify their validity for EU countries.

Moreover, EKC studies are based on different proxies of environmental quality. One of the most general attitudes aimed at capturing all environmental impacts is to estimate the EKCs for total energy use [19,23]. The results usually indicate a monotonic increase in energy usage along with income per capita, although this does not preclude an inverted U-shaped curve [19,20,27,31]. Some results [21] suggest long-term relationships between economic growth, energy consumption and energy pollutants and, hence, confirm the EKC hypothesis with energy consumption as a major contributor to energy pollution. Moreover, researchers [22] suggest that the high share of manufacturing in total GDP is associated with higher levels of energy consumption and, thus, a structural shift may induce the occurrence of the energy Kuznets curve.

Independently of the EKC hypothesis itself, it is worth stressing that energy goals are strictly connected with the condition of the natural environment as well as other dimensions of human existence and if achieving them is sectoral specific, then it is important to specify the existence of such relationships.

Thus, the aim of the study is to identify interferences between the sectoral structure of production and the state of energy usage and production in the context of the SDG 7 in the EU-28 states. The paper verifies an initial general hypothesis that sectoral features differentiate the energy achievements, that is the countries that differ concerning sectoral proportions in gross value added (GVA) differ also by their energy performance. It is tested adopting a static approach, basing on comparisons between national economies in 2018. The approach cannot directly prove any causality; however, it may indicate whether sectoral pattern of production is a factor interfering with differences in energy performance or not.

The aim covers:

- comparing energy usage and production across EU countries and specifying the leaders and the laggers. A detailed hypothesis verified at the research stage assumes higher energy achievements in more affluent countries, in accordance with the EKC for advanced economies.
- distinguishing groups of EU countries expressing variety of structural patterns for production. A detailed hypothesis assumes that the groups differ in relation to their levels of economic development expressed as GDP per capita and the higher the GDP per capita, the higher the share of knowledge-based services and the lower the share of agriculture, in accordance with sectoral development theory.
- identifying the differentiating potential of sectoral features for energy achievements across the dimensions of energy achievements and specific industries. More detailed hypotheses assume that relationships appear at least between the final and primary energy consumptions, energy productivity and greenhouse gas emissions as well as economic structure and that the more industrialized an economy becomes, the more severe the energy problems they encounter.

Our findings indicate no clear relationships between general energy achievements and structural features; however, some unexpected interlinkages can be identified. The results concerning the energy performance of EU countries offer some support for an increase in energy tensions along with production level and, thus, do not confirm the EKC positive assumption of declining environmental pressure in more affluent economies. Moreover, while structural patterns in production differ according to GDP per capita, revealing a typical shift from agriculture and industry towards knowledge-based services, their relations with energy achievements are not so obvious. The interference refers to primary and final energy consumptions, which may be a direct relation induced by different patterns of energy use in different industries, as well as to energy poverty, which in turn reflects indirect linkages occurring through average income level. Another finding is that the explanatory role of energy achievements is not clearly fulfilled by the "polluting" industrial sector of the economy, which unexpectedly appears to be linked positively to aggregated energy sustainability while does not reveal relations with detailed indices of energy performance. Of importance are the structural features of economies, such as the shares of agriculture, traditional services and finance in total production. What is especially important, is that the relation seems not to result from technological specificity or the energy needs of these sectors but rather expresses sectoral linkages with GDP per capita. Some trade-offs concerning sectoral influence on different energy goals seem to be a cause for the lack of a general relation between aggregated energy achievements and production structure. This ambiguity does not reject the research hypothesis; rather, it suggests a need to research the possible interlinkages between different dimensions of SD at a more disaggregated level, with more attention placed on possible trade-offs and synergies.

2. Materials and Methods

The study deals with two important aspects of development: the structural features of an economy and the characteristics of energy usage and production. It compares 28 European Union member states in year 2018, considering the possible relations between the two dimensions of development. To provide a longer horizon for the relationships, the main results were supported by comparisons for 2010.

The structural features of an economy are defined as proportions of sectoral contribution into total activity and specified in terms of the classification sections under Statistical Classification of Economic Activities in the European Community, Rev. 2 (NACE Rev. 2). Data in this field are arranged according to Eurostat grouping, with a breakdown of 10 industries:

- Agriculture, forestry and fishing (A);
- Industry (except construction) (BCDE);
- Construction (F);
- Wholesale and retail trade, transport, accommodation and food service activities (GHI);
- Information and communication (J);
- Financial and insurance activities (K);
- Real estate activities (L);
- Professional, scientific and technical activities; administrative and support service activities (MN);
- Public administration, defence, education, human health and social work activities (OPQ);
- Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies (RSTU).

Economic activity is expressed by gross value added (GVA) in millions of euro, at current prices. The most current data were used, from the year 2018 and supplemented by data for 2010. The share of each section group in the total economic activity (totaling 100%) was calculated to enable comparability between the different scales of the economies. All data were extracted from the Eurostat database [32].

The energy usage characteristics were described in line with the European Union Sustainable Development Goals (EU SDGs). Goal 7: "Ensure access to affordable, reliable, sustainable and modern energy for all" (SDG 7) was monitored by a set of 6 indices (with one of them being presented in more detail as 2 separate indicators) and 1 multi-purpose indicator. For the purpose of the study, they were derived from the EU SDG indicator set prepared by Eurostat:

- Primary energy consumption [SDG_07_10]—tonnes of oil equivalent (TOE) per capita [33];
- Final energy consumption [SDG_07_11]—tonnes of oil equivalent (TOE) per capita [34];

- Final energy consumption in households per capita [SDG_07_20]—kilogram of oil equivalent (KGOE) [35];
- Energy productivity [SDG_07_30]—PPS per kilogram of oil equivalent (KGOE) [36];
- Share of renewable energy in gross final energy consumption by sector [SDG_07_40]—percentage [37];
- Energy import dependency by products [SDG_07_50]—percentage [38];
- Population unable to keep home adequately warm by poverty status [SDG_07_60]—percentage [39];
- Greenhouse gas emissions (source: EEA) [SDG_13_10]—tonnes per capita [40] (original indicator Greenhouse gas emissions intensity of energy consumption [SDG_13_20]—available only as index, 2000 = 100 was replaced to ensure comparability across the countries).

All data on the SDG 7 described the achievements from the year 2018 by the EU countries towards affordable and clean energy, concerning consumption, supply and accessibility, as targeted in the UN's "2030 Agenda for Sustainable Development". However, they were also supplemented by indicators for 2010 year, as the initial for the "Europe 2020 strategy".

Moreover, data on final energy consumption by sectors: industry, transport, commercial and public services and households (thousand tonnes of oil equivalent (TOE)) in 2018, extracted from Eurostat database [41], were used to give a more general view on energy usage patterns across the economies. As, in the database, agriculture is not distinguished as a separate sector, its share in total energy consumption was computed as residual. It may lead to some inaccuracy of estimation; however, allows to draw a general view of a contribution of each sector into energy consumption.

The study was based on the preliminary assumption that development is a multidimensional process and all its dimensions are mutually related. Structural features of economic activity in terms of industry breakdowns may be decisive for patterns of energy usage and production. Thus, the economic structure of production may influence the progress of a country towards its energy targets for sustainable development (SD). The aim of the paper was to identify empirically the occurrence of such relations.

We verified the hypothesis that the structural patterns of economies describe their progress towards SDG 7. To fulfil this task, we adopted a static approach and followed three steps:

1. Identify the achievements of the EU-28 states towards the SDG 7 using a synthetic measure of development.
2. Identify structural patterns in the economic activity of EU states by grouping the economies according to their branch structure of gross value added.
3. Verify differences in energy usage and production between the specified groups of economies.

For the first stage of our research taxonomic linear ordering methods, which are used to rank objects (e.g., countries) described by multidimensional characteristics, were adopted. In linear ordering empirically observed diagnostic variables are a base to calculate a synthetic indicator. The synthetic indicator may be specified adopting approach with a target model or without it. The Hellwig concept [42], which was a base for the study, assumes the former solution. In these group of ordering methods, the objects (countries) may be ranked by calculating a distance to the target. In the study, the synthetic indicator was calculated to measure development towards the SDG 7 by each of the EU-28 states. All 8 indicators of the SDG 7 were taken into account, of which 2 were specified as stimulants (SDG_07_30 and SDG_07_40) and 6 as destimulants (SDG_07_10, SDG_07_11, SDG_07_20, SDG_07_50, SDG_07_60, SDG_13_10). According to the method:

- values of the indicators were standardized (using the average value and standard deviation);

- the target model was specified with maximum values of the stimulants and minimum values of the destimulants (as well as the anti-model with minimum values of the stimulants and maximum values of the destimulants);
- distances between the objects (countries) and the target model were calculated using the Euclidean distance formula, which is a geometric mean of variables in multi-dimensional space;
- the synthetic indicator was calculated based on the formula:

$$SM_i = 1 - \frac{d_i}{d_0} \quad (1)$$

where d_i—Euclidean distance between object i (country) and the target model; d_0—Euclidean distance between the target model and the anti-model. It is a slight modification of the Hellwig method, however, allows to avoid negative signs of the *SM*.

The synthetic measure SM_i adopted values in the range [0;1]. The value 0 described the anti-model and the value 1 the target model and for each object the higher the value, the better results achieved.

Finally, a ranking of the EU-28 states concerning their energy performance (*SM*) was specified. To compare the results in time, similar *SM* was calculated for 2010 and Spearman's rank correlation coefficient allowed to check similarity of the rankings.

During the second stage, clustering of the EU economies according to their sectoral structures of production in 2018 was based on the Ward agglomeration method [43]. The Ward method assumes adopting a minimum variance criterion that minimizes the total within-cluster variance. It is perceived as one of the most effective classical methods of agglomeration, by leading to clustering with an equalized although not numerous quantity of objects [44,45]. For clustering we used Euclidean distance as a "natural" measure of distance between the objects. The variables were not standardized because we took into account the share of each industry in the total value added. Statistica software was used for the calculations.

During the third stage, the analysis of variance (ANOVA) was used to verify whether differences concerning energy usage and production among groups of economies were essential. The single-factor ANOVA F-test allowed a p-value to be specified and compared with an assumed value $\alpha = 0.05$ to verify any statistically significant differences between the groups concerning their energy performance.

The clusters were also tested for differentiation by a general level of economic development, measured by GDP per capita (GDP at market prices, current prices, euro). In this case Eurostat data for 2018 [46] were used. The relations between GDP per capita, structural features and energy usage shed some light on the character of the causality. GDP per capita for 2010 [46] were also used in the study to check stability of the results in time.

The study also tracked in detail the potential relations between sectoral features and the energy characteristics of the economies. It attempted to identify those sectors with any connection to energy achievements. To fulfil the task, the Pearson's correlation coefficient was adopted and tested at the $\alpha = 0.05$ level to examine whether the relations were statistically significant.

3. Results

The results are divided into sections to aid verification of the main hypothesis concerning the explanatory role of structural features of production in terms of energy use and production in the EU-28 states.

The preliminary assumption is supported by general data related to energy consumption in different sectors (see Figure 1).

For the EU-28 more than 30% of the energy was used by transport, ranging from 17% in Finland to 56% in Luxembourg. This sector was, thus, of most importance for achieving the energy targets. Households were responsible for nearly 27% of energy consumption, with the highest share in Croatia (34%) and the lowest in Luxembourg

(13%), indicating essential differences in lifestyle, as well as the scale of complementing—productive activities between the countries. Industry was responsible for nearly 25% of the energy usage, with the lowest amounts used in Malta (11%) and the highest in Finland (44%). The 10 percentage points lower share in energy consumption (about 14%) occurred with commercial and public services, at about 8% for Romania and 24% for Malta. This suggests that the development of a service economy typical for the most advanced stage of development should reduce energy usage and, thus, enable the fulfilling of the SDG 7. The lowest share (just above 3%) characterized agriculture, ranging from 9% in the Netherlands to merely 0.6% in Luxembourg. Agriculture also had the highest variation across the EU-28 states (coefficient of variation CV = 53%). Comparing shares of agriculture in energy consumption and GVA indicates that the sector is relatively energy intensive and may negatively influence the SDG 7; however, the feature may be very diversified.

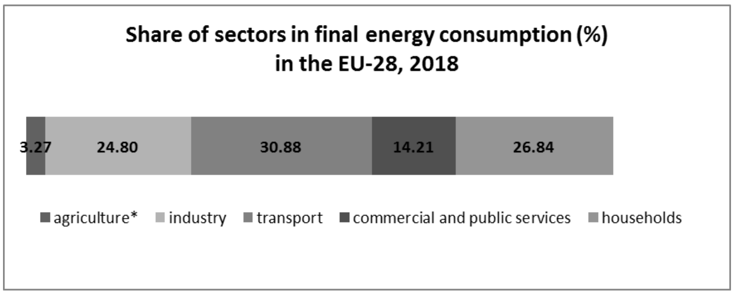
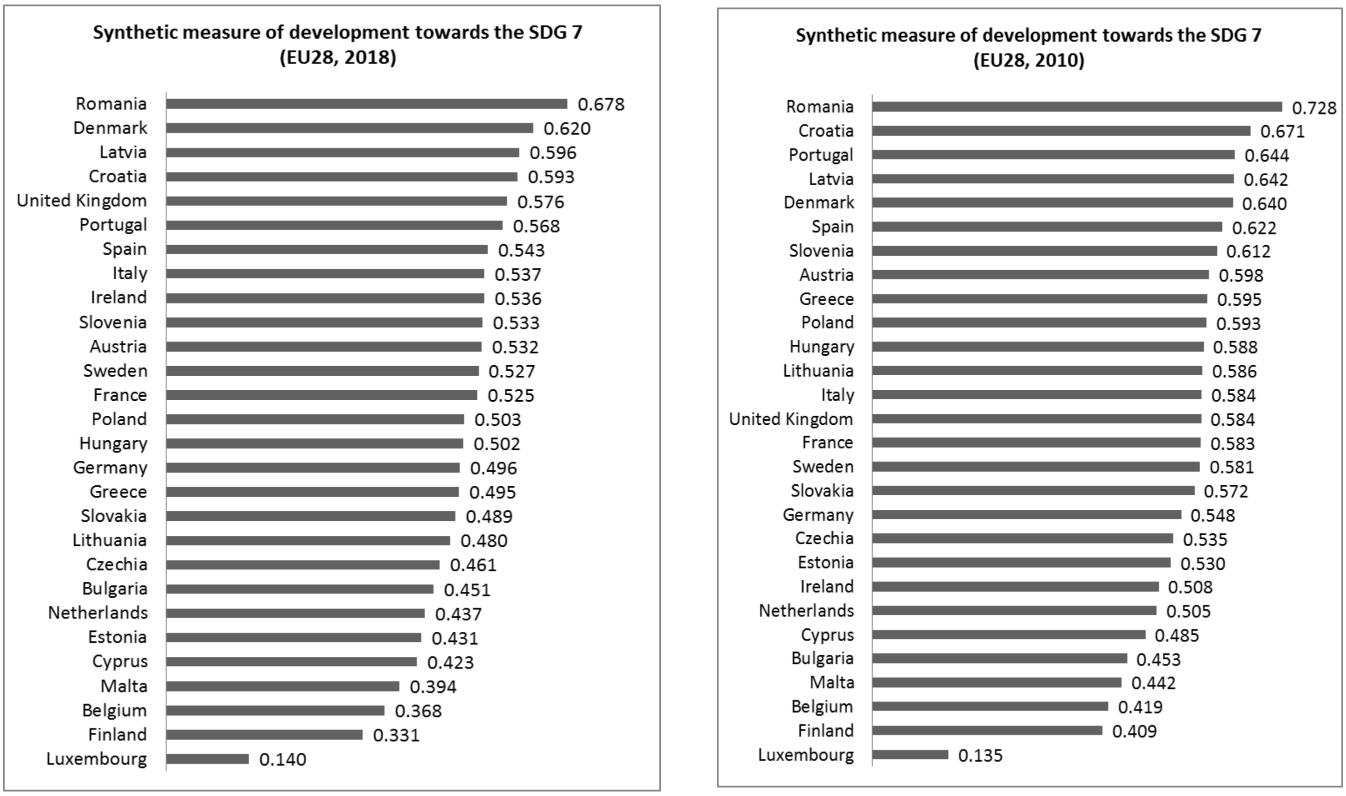


Figure 1. Share of sectors in final energy consumption (%) in the EU-28 states in 2018. Source: Own calculation based on [41]. * share of agriculture is computed as residual.

3.1. Achievements towards the SDG 7 in the European Union Member States

The first stage assumed a diagnosis of the achievements by the EU-28 states of the energy goals. A ranking of the countries in 2018 based on a synthetic measure (SM) is presented in Figure 2a. It may be compared to a ranking in 2010 (Figure 2b), as in the initial period for the "Europe 2020 strategy".

Our results revealed that the most advanced in economic development and affluent economies were not the leaders in fulfilling the energy goal. Romania, which had one of the lowest GDP rates per capita, achieved the highest score, while Luxembourg, the wealthiest state, achieved the lowest score. The position of Romania was derived from its lowest levels of primary and final energy consumption, supported by high ranks (three) in energy productivity, import dependency and greenhouse gas emissions. A relatively low production may be a reason for such results. As its economy is still catching up, it is expected that it will increase its low energy consumption and greenhouse gas emissions and, thus, its position. An important challenge for Romania is to take advantage of the newest, more environmentally friendly technologies in the course of economic development. The score of Luxembourg also resulted from primary and final energy consumption and greenhouse gas emissions, the highest across the EU-28 states. Moreover, Luxembourg also performed relatively poorly concerning energy consumption in households, import dependency and renewable energy (27th or 26th place). In addition, in this case, a high production level may be responsible for such unfavorable energy performance. Relatively poor scores were also achieved by other affluent economies, such as Finland, Belgium and the Netherlands. Moreover, Latvia and Croatia (both with relatively low GDPs per capita) were among the five best performing states in terms of the SDG 7. The correlation coefficient between GDP per capita and SM value was negative and statistically significant (-0.50) (calculation based on [33–40,46]), demonstrating that the richer countries tended not to reduce their negative influence on the environment in the energy sphere. Some countries broke this rule, such as Denmark and the UK (and to some extent also Austria and Sweden), proving that reducing energy usage was possible even with high production and that their energy solutions could be considered as potential benchmarks. The observation was that the level of production was an important although not decisive factor of energy usage, leading us to consider the structure of production as a potential explanatory factor.



(**a**) (**b**)

Figure 2. Synthetic measure of development towards the SDG 7 for the EU-28 states in 2018 (**a**) and in 2010 (**b**). Source: Own calculation based on [33–40].

Moreover, it appeared that the ranking of the EU-28 states is relatively stable concerning the period between 2010 and 2018. At the beginning of the initiative "Europe 2020" it revealed a similar pattern of higher energy achievements in less-developed economies and less environmentally friendly performance in the most affluent countries (with correlation coefficient −0.63). Although the values of SM in 2010 and 2018 are not directly comparable because of construction of the measure, the rank correlation was high (0.87), confirming similarity of results in energy usage and production. It also indicates that changes towards the SDG 7 are a challenging and longstanding task.

3.2. Structural Patterns of Economic Development in the European Union Member States

The sectoral structure of gross value added formed a basis to group the EU-28 states into clusters sharing similar industrial patterns in terms of economic development. The results of the cluster analysis are presented in Figure 3.

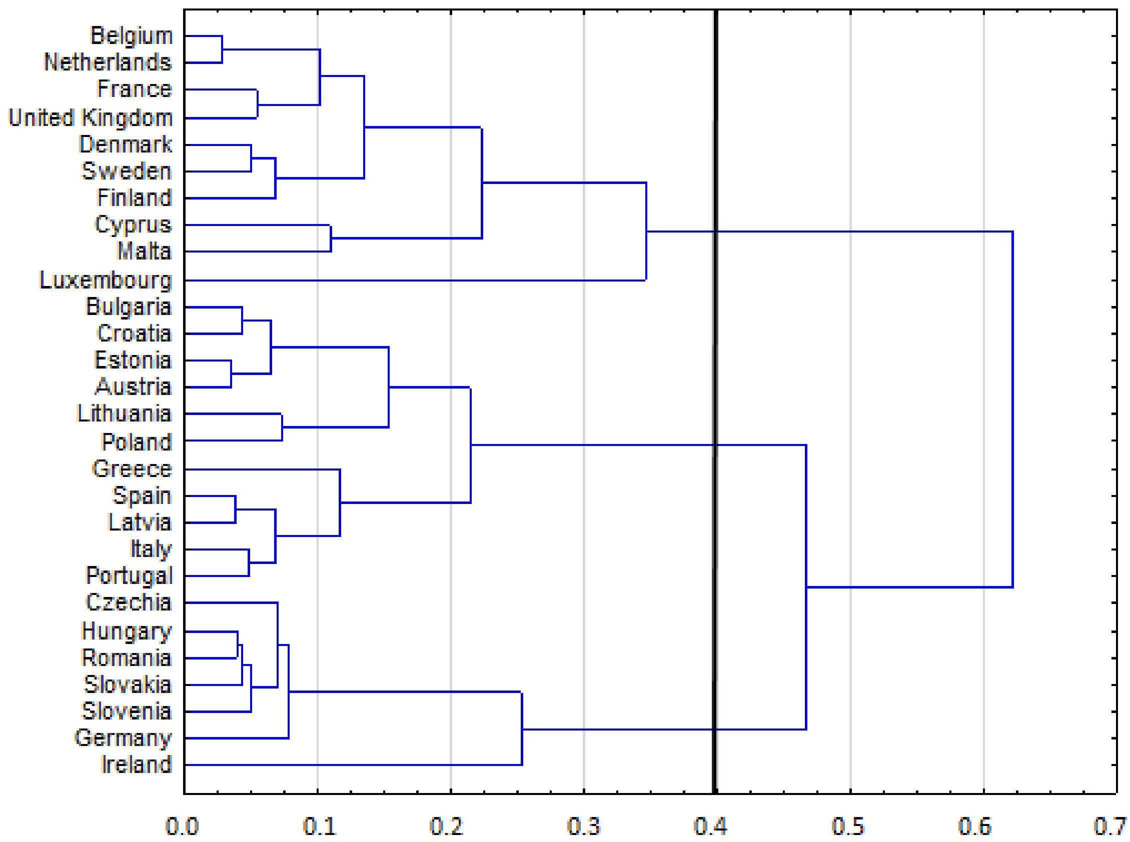


Figure 3. Clustering results—dendrogram (Ward method, Euclidean distance) for the EU-28 states concerning their sectoral structure of gross value added in 2018. Source: Own calculation based on [32].

We decided to stop the clustering at a distance 0.4 and, thus, grouped the EU countries into three clusters. Cluster 1 had 10 economies, Cluster 2 had 11 and Cluster 3 had 7. Their structural features are presented in Table 1.

Table 1. Sectoral features of the groups of EU countries.

Share of NACE Section(s) in GVA (%)	**Group 1**		**Group 2**		**Group 3**	
	Belgium, Denmark, France, Cyprus, Luxembourg, Malta, Netherlands, Finland, Sweden, United Kingdom		**Bulgaria, Estonia, Greece, Spain, Croatia, Italy, Latvia, Lithuania, Austria, Poland, Portugal**		**Czechia, Germany, Ireland, Hungary, Romania, Slovenia, Slovakia**	
	Avg. (%)	**CV (%)**	**Avg. (%)**	**CV (%)**	**Avg. (%)**	**CV (%)**
A	1.4	57	3.0	32	2.6	58
BCDE	14.1	32	19.4	17	27.6	16
F	5.8	17	5.4	33	5.4	29
GHI	19.0	16	24.6	12	17.8	18
J	6.0	19	4.5	27	6.1	49
K	8.0	83	4.6	26	3.9	27
L	9.8	26	10.7	30	8.8	17
MN	12.8	21	8.1	18	9.8	16
OPQ	19.7	11	16.6	12	15.2	16
RSTU	3.5	59	3.1	27	2.8	31
GDP pc (euro)	44,660	47	20,004	49	27,226	74

Avg.—Average/Arithmetic mean. CV—Coefficient of variation. Source: Own calculation based on [32,46].

Cluster 1 consisted of the most advanced economies, as reflected by their average GDP per capita. Their structural characteristics were also the most advanced as the average share of agriculture (A) as well as industry (BCDE) was the lowest. Their stage of development reflected the introduction of a service knowledge-based economy. This was specified, in particular, by the highest share of professional services (MN). Moreover, the economies were characterized by the strongest financial sector (K) and the essential role of welfare services (OPQ). The last feature might indicate an essential role of the state in the economies.

Cluster 2 was the most numerous one and simultaneously the least developed in terms of general economic results, expressed in GDP per capita. The structural features revealed the highest share of agriculture. Service sector development was at the initial stage as the cluster was specified by the highest share of traditional services (GHI) and the lowest was the role of ICT activities (J), as well as professional services (MN). The cluster was also characterized by the highest importance of real estate activities (L), which might reflect dynamic changes occurring within the economies.

Cluster 3 was the least numerous and its decisive feature was strong industrialization (BCDE). Moreover, industrial sector development was supported by more modern solutions, expressed by the highest share of the ICT sector (J). However, most of service activities were characterized by the lowest share among the clusters, which concerned both traditional ones (GHI) as well as financial (K) and welfare services (OPQ).

Generally, the clustering results confirmed a universal pattern in structural development along with growing GDP per capita. The least affluent countries were the most agrarian, then industrialization led to an increase in the level of production and, finally, the richest countries were characterized by knowledge-based service economies.

3.3. Achievements towards the SDG 7 and the Structural Patterns of Economic Development

Our initial hypothesis assumed that energy usage and production were influenced by the industrial structure of an economy. To verify this statement, we adopted a static approach and checked differences in each of the SDG 7 indicators between each of the three clusters of the EU-28 states. The comparisons across clusters cannot directly prove any causality; however, they may generally suggest whether sectoral pattern of production is a factor interfering with differences in energy performance or not. The general energy characteristics and the results of the test for validity of between-group differences are presented in Table 2.

Table 2. SDG 7 indicators in the 3 clusters of EU-28 states in 2018.

SDG 7 Indicator	Group 1		Group 2		Group 3		Analysis of Variance: *p*-Value
	Belgium, Denmark, France, Cyprus, Luxembourg, Malta, Netherlands, Finland, Sweden, United Kingdom		Bulgaria, Estonia, Greece, Spain, Croatia, Italy, Latvia, Lithuania, Austria, Poland, Portugal		Czechia, Germany, Ireland, Hungary, Romania, Slovenia, Slovakia		
	Avg. (%)	CV (%)	Avg. (%)	CV (%)	Avg. (%)	CV (%)	
SDG_07_10	3.97	42	2.69	29	2.94	24	0.0491 *
SDG_07_11	3.14	53	1.95	25	2.15	23	0.0455 *
SDG_07_20	639.10	37	500.55	32	541.00	22	0.2327
SDG_07_30	8.16	31	8.46	21	9.87	42	0.4437
SDG_07_40	20.65	81	24.74	34	15.99	30	0.3149
SDG_07_50	60.72	48	55.76	42	52.15	31	0.7635
SDG_07_60	5.64	107	13.74	78	4.80	51	0.0329 *
SDG_13_10	9.89	44	8.57	31	9.31	30	0.6745
SM	0.434	32	0.521	10	0.528	13	0.0834
GDP pc (euro)	44,660	47	20,004	49	27,226	74	0.0096 *

Avg.—Average/Arithmetic mean. CV—Coefficient of variation. SM—synthetic measure of development towards the SDG 7. * statistically significant at 0.05. Source: Own calculation based on [32–40,46].

Cluster 1 appeared to encounter the highest level of energy usage, concerning primary and final consumptions and consumption in households, as well as the highest greenhouse gas emissions. Moreover, it also had the lowest energy productivity, indicating that the countries were not taking advantage of the economies of scale in production and an increase in production led to growing energy usage. The cluster also faced the severe problem of energy import dependency, which may be induced by continuously growing demand for energy. Generally, it seemed that the most economically developed cluster was still far from energy neutrality, stemming from the fact that a high level of production required high energy usage.

In contrary, Cluster 2 was characterized by the lowest primary and final energy consumptions, consumption in households and greenhouse gas emission. The profile of energy consumption was also favorable as the share of renewable energy was the highest in the group. However, the cluster was coping with the severe problem of energy poverty, which was related to the more general issue of material poverty specified by low incomes.

Cluster 3 could be distinguished as having the most favorable indicators of energy dependency as well as energy poverty. Moreover, its energy productivity was the highest among the clusters. Nevertheless, its structure of energy consumption was specified by the lowest share of renewable sources and this feature might be attributed to a very traditional industrial structure of production.

Despite the above distinguishing features of each cluster, an analysis of variance confirmed essential differences between the groups only in the case of primary energy consumption, final energy consumption and energy poverty. It appeared that for most of the SDG 7 indicators the in-cluster differences were too significant to unambiguously attribute an energy specificity to the clusters. However, the clusters differed significantly concerning their economic results in terms of GDP per capita. Hence, some traditional patterns in development might be indicated, as the poorest economies were still using less energy than the wealthier ones and, thus, the former might be more environmentally friendly. This indicates that within the EU the pattern of development still seemed to reflect the initial part of the EKC and there remained much to do towards the SDG 7 concerning all European societies.

An in-depth analysis of the relations between the structural features of economic production and energy characteristics aimed to identify the specific kinds of activity that correlated with energy usage and production. The correlation matrix is presented in Table 3.

Table 3. Correlation matrix between structural features of economy and the SDG 7's indicators for the EU-28 states, 2018.

SDG 7 Indicator	Share of NACE Section(s) in GVA									
	A	**BCDE**	**F**	**GHI**	**J**	**K**	**L**	**MN**	**OPQ**	**RSTU**
SDG_07_10	−0.48 *	−0.17	0.31	−0.48 *	0.23	0.55 *	−0.09	0.23	0.24	−0.42 *
SDG_07_11	−0.49 *	−0.25	0.24	−0.45 *	0.21	0.71 *	−0.15	0.25	0.18	−0.37
SDG_07_20	−0.33	0.08	0.39 *	−0.43 *	0.12	0.15	0.00	0.08	0.25	−0.48 *
SDG_07_30	−0.20	0.31	−0.30	−0.30	0.39 *	0.14	−0.03	−0.06	−0.30	−0.24
SDG_07_40	0.23	0.04	0.32	0.12	−0.07	−0.33	0.23	−0.38 *	0.24	−0.10
SDG_07_50	−0.27	−0.36	−0.35	0.10	−0.08	0.42 *	−0.09	0.31	0.02	0.30
SDG_07_60	0.46 *	−0.16	−0.35	0.64 *	−0.17	−0.07	0.24	−0.47 *	−0.16	0.05
SDG_13_10	−0.45 *	−0.03	0.01	−0.28	0.31	0.65 *	−0.25	0.08	−0.16	−0.47 *
SM	0.41 *	0.38 *	−0.03	0.20	−0.17	−0.69 *	0.21	−0.32	−0.08	0.09
GDP pc (euro)	−0.74 *	−0.19	−0.06	−0.61 *	0.44 *	0.69 *	−0.17	0.46 *	0.18	−0.24

SM—synthetic measure of development towards the SDG 7. * statistically significant at 0.05. Source: Own calculation based on [32–40,46].

There were several types of economic activity that correlated significantly with some detailed indicators of energy usage and production: agriculture (A), traditional services (GHI), financial activities (K), with four indices; other services (RSTU), with three indices; professional business services (MN), with two indices; and construction (F) and ICT activities (J), with one indicator. Unexpectedly, there was no confirmed relation between any individual energy goal and the role of industry in the economy. Nevertheless, industry did correlate with the aggregated energy achievements (SM), which drew attention to the mutual interlinkages between energy goals.

Some of the identified correlations took an unexpected sign, inconsistent with the EKC assumptions of "polluting" industry and "clean" services. We examined the details to consider which were the most essential.

For agriculture, we observed that when the role of the agricultural sector was high, both primary and final energy consumptions, as well as greenhouse gas emissions were limited, indicating that agriculture was not responsible for most energy pressures. However, a high share of agriculture in an economy appeared together with energy poverty, stressing the rural character of many social problems. Deagrarization is a trend universal for economic development, as was confirmed by the correlation with GDP per capita. Simultaneously, the process of development encompasses greater energy use for production purposes and, thus, the relation with agriculture might be an indirect one. As poverty, including in the energy dimension, is induced by low income, then development and deagrarization might alleviate it. Thus, some trade-offs existed concerning the influence of agricultural production on the energy goals (limiting energy usage and greenhouse gas emissions but inducing energy poverty).

Similar considerations might be true for traditional services (trade, transport, accommodation and food service activities), where the role grew at the initial stage of service economy development, usually as supporting activities for industrial production. In more advanced economies, their share in economic production tends to decrease, probably causing the negative correlation with energy consumption (primary, final and in households), and this intermediary nature of the relation was responsible for the lack of support for the EKC thesis. Moreover, as the sector usually employs less qualified people, jobs in traditional services are typically low-paid and low-secure, inducing poverty problems.

The opposite relations may be described for financial activities (K). Their development is often perceived as a sign of economic advancement and characterizes the most affluent economies. It goes in line with high energy consumption (primary and final), greenhouse gas emissions and energy dependency. The relations are not of a causative nature but are an indirect one.

Generally, the synthetic measure of energy performance SM revealed some interlinkages with traditional kinds of activities, namely agriculture and industry, as well as with financial activity perceived as a sign of structural advancement. In the first case, the positive correlation coefficient indicated that the economies with high shares of traditional activities were also those with more environmentally friendly patterns of energy production and usage. In the second case, the coefficient was negative, indicating more severe energy tensions in economies with a high share of financial GVA. The observations suggested an indirect nature for the relationships between economic structure and energy performance, expressing the directions of structural change within the process of economic development.

In summary, the relations of the structural features to energy usage and production were mainly of an indirect nature, reflecting a connection with the general level of economic development. The connection could be observed for the SDG 7 indicators: primary energy consumption (four significant correlation coefficients), final energy consumption (three), energy consumption in households (three), energy poverty (three) and greenhouse gas emission (three). Three out of the five energy indicators distinguished the specified clusters of the EU-28 states. Unexpectedly, only one correlation coefficient detailed a relation concerning energy productivity: those having an ICT industry and which supported the EKC thesis about the positive influence of the information sector on the environment.

Moreover, the results appeared to be similar concerning 2010. As shown in Table 4, SM for 2010 was also positively correlated with a share of agriculture and industry in GVA, while it negatively correlated with financial activities. It confirms stability of potential relationships between sectoral structure of production and energy performance.

Table 4. Correlation matrix between structural features of economy and the SDG 7's indicators for the EU-28 states, 2010.

SDG 7 Indicator	Share of NACE Section(s) in GVA									
	A	**BCDE**	**F**	**GHI**	**J**	**K**	**L**	**MN**	**OPQ**	**RSTU**
SDG_07_10	−0.55 *	−0.28	−0.13	−0.38 *	0.33	0.59 *	−0.10	0.43 *	0.19	−0.26
SDG_07_11	−0.53 *	−0.34	−0.17	−0.31	0.30	0.70 *	−0.14	0.36	0.14	−0.27
SDG_07_20	−0.39 *	0.05	−0.34	−0.34	0.34	0.20	−0.12	0.44 *	0.25	−0.47 *
SDG_07_30	−0.21	−0.14	−0.21	−0.06	0.05	0.14	0.21	−0.07	0.23	−0.07
SDG_07_40	0.37	0.32	0.09	0.09	−0.05	−0.44 *	0.06	−0.29	0.04	−0.23
SDG_07_50	−0.29	−0.43 *	−0.11	0.21	−0.03	0.36	−0.03	0.09	−0.01	0.35
SDG_07_60	0.52 *	−0.06	0.23	0.33	−0.24	−0.04	0.17	−0.50*	−0.28	0.00
SDG_13_10	−0.50 *	−0.33	−0.18	−0.25	0.27	0.74 *	−0.15	0.25	0.04	−0.25
SM	0.47 *	0.45 *	0.18	0.19	−0.31	−0.77 *	0.17	−0.30	0.01	0.01

SM—synthetic measure of development towards the SDG 7. * statistically significant at 0.05. Source: Own calculation based on [32–40,46].

4. Discussion

The general results of the study do not confirm the hypothesis related to the explanatory role of the sectoral structure of production in terms of the energy characteristics of the EU-28 states in the context of the SDG 7. Nevertheless, the results are rather ambiguous as there are some signs of possible relations in line with economic structure to energy production and usage. First, by easing the statistical restriction and setting a significance level at $\alpha = 0.1$, the analysis of variance confirmed the differences between the clusters of EU-28 states concerning their synthetic measure of achievements towards the SDG 7. Moreover, even at significance level $\alpha = 0.05$, the differentiation is essential for some indicators of the SDG 7, namely final and primary energy consumptions and energy poverty. Finally, identification was possible for some essential correlations between the energy indicators and the sectoral characteristics, especially those concerning the share of agriculture, industry, traditional services and financial activities in GVA. All these findings suggest a need to extend the search for interlinkages between structural features and energy achievements.

Other interesting results concern the role of industry in energy performance. Detailed correlations with individual energy goals appeared to be not significant, while aggregated energy achievements correlated positively with the share of industry in the GVA. The finding stresses the importance of mutual interlinkages: synergies and trade-offs between detailed energy goals. This suggests a need for further research into specifying such interlinkages. Generally, the industrial activities did not appear to be causing the most severe environmental tensions in the EU, suggesting that new energy technologies are not sectoral specific.

The study adopts an aggregated approach to both energy goals as well as the structure of an economy. A synthetic measure of energy achievements was used to simultaneously take into account the different problems related to energy consumption, supply and accessibility. However, this may be misleading, as there are some trade-offs and unintended consequences between the individual energy goals of SD, such as between energy consumption in households and energy poverty. Nevertheless, it creates the opportunity to capture the general specificity of the economy and to compare achievements between the countries. Ranking of the EU-28 states based on their energy achievements is an important outcome of our study and indicates the generally more environmentally friendly characteristics of less affluent economies. A similar ranking was achieved by Kiselakova et al. [47]. This observation supports some theses about the monotonic growth of energy pressures on the environment within the process of economic development [23]. Once again, the relation identified in our study was not strong (correlation between the GDP per capita and the *SM* value was −0.5) and, thus, it is not able to reject the EKC hypothesis. Moreover, the causal functional relation was not intended to be tested in the study and the correlation coefficient used here merely signaled the possibility of unidentified mutual interlinkages.

Numerous studies on the existence of the EKC curve still do not achieve a common conclusion, even though sophisticated techniques have often been used with different indicators adopted to specify environmental tensions [19–31]. Some of them focused on energy consumption as a general factor of environmental pressure and tested the EKCs for total energy use, seen as a proxy indicator for all environmental impacts [23]. Shahbaz et al. [21] confirmed the existence of long-term relationship between economic growth and energy intensity; in addition, in another study [27], the relationship between economic growth, energy consumption and energy pollutants indicated energy consumption as a major contributor to energy pollution. Acaravci and Ozturk [27,48] examined the causal relationship between carbon dioxide emissions, energy consumption and economic growth for some European countries, confirming it only in a few cases. Unidirectional causality between financial development and CO_2 emissions was identified by Chang et al. [49] and related to industrial structure. Similarly, the inclusion of sectoral features identified energy consumption as an important factor for manufacturing GDP [21,50] and generally, as Dinda [22] claims, a high share of manufacturing in total GDP is associated with higher levels of energy consumption. On the contrary, Jober and Karanfil [21,51] report that there is no causality between energy consumption and economic growth at the aggregate level and at the sectoral industry level. In addition, Luzzati and Orsini [27,31] do not support an energy-EKC hypothesis after studying the relationship between absolute energy consumption and GDP per capita. A number of studies adopted a dynamic approach and tested causality between the variables. In contrast, this study takes a static approach and attempts to identify whether any interference between sectoral structure and energy performance measured at an aggregated level exists. This is checked by testing differences in the SDG 7 indices between clusters of countries specified by structural patterns of production.

In this vein, our findings suggest that there exists a relationship between the structure of production and the final and primary energy consumptions; however, the relationship is mainly induced by interlinkages with agricultural production, traditional services (with a positive environmental impact) and financial services (with a negative impact). As agricultural production is usually connected with "a clean economy", the assumption is confirmed by its positive correlation with general energy performance. It is specified not only by low energy consumption and greenhouse gas emissions, as detailed relations in our research suggest, but also, as other researchers point out [52], agriculture is expected to supply an economy with most of the energy renewable resources, thus fulfilling the climate and energy goals. The unexpected signs of the correlation coefficients in the case of traditional services and financial services indicate that the relation is not a direct one (as there is no explanation why the financial sector should itself consume a lot of energy or that traditional services such as transport should be less energy consuming), but it expresses a general level of economic development (as the advanced post-industrial knowledge-based countries with a high level of GDP per capita appear to be more energy consuming). It suggests that the EU-28 states still have to reach the level at which the environmental pressure can be essentially lowered and that there exist yet more reasons to doubt the validity of the EKC.

The study notes that important linkages can be specified between the problems of energy poverty and the structural features of production. The idea of a structural basis for economic poverty was sought, e.g., by Loayza and Raddatz [53] to indicate the alleviating role of labor-intensive sectors, such as agriculture, construction and industry. On the other hand, the service sector was specified as the most favorable for limiting the risk of poverty by Cyrek [54] and Ghani and Kharas [55], while Cyrek and Cyrek [56] found that the most socially favorable results were typical for employment in other knowledge-intensive services in contrary to market knowledge-intensive services. Thus, the results are ambiguous and do not allow definite indications as to the role played by the structural patterns of development in terms of material poverty. The findings depend on the method, data, geographical scope and period of analysis, indicating the specificity of the poverty problems faced by economies at different stages of economic development. Our study focuses on the relatively homogenous group of EU-28 states and finds that poverty in its energy dimension is induced by a low level of economic advancement expressed by a high role of agriculture and traditional services, which can be alleviated within the developmental process towards economies with a higher share of business services. Moreover, the relationship between the sectoral structure of production and energy poverty may either have a direct (connected with inter-sectoral differences in incomes and wages) or indirect character (specified by a general level of social welfare). The character of such interlinkages appears to be an interesting field for future research.

5. Conclusions

The paper empirically contributes to a relatively neglected issue of relations between sectoral features of the EU economies and their energy performance as interlinked dimensions of sustainable development. It adopts a static approach to search for such connections; however, it expresses a holistic attitude to SD. It searches for interlinkages between multi-dimensional features of these phenomena, in contrary to the more common focus on one chosen characteristic of energy performance (e.g., CO_2 emissions) or sectoral structure (e.g., a share of manufacturing in economy). It considers simultaneously shares of many sectors in production and, thus, does not limit sectoral advancement to one sector. Similarly, energy achievements are measured by a synthetic measure which aggregates detailed indices. The aggregated general approach allows to catch existence of some synergy and trade-offs between detailed dimensions and indicates that some phenomena are not simply additive. Thus, it gives different results than the research on partial relations.

The research presented in this study indicates the indirect character of the relationships between the sectoral structure of production and energy sustainability across the EU-28 states. The main hypothesis concerning the differentiating role of structural patterns for energy performance in the context of the SDG 7 was not confirmed, at least at the aggregate level. Nevertheless, it was possible to identify some detailed relationships that still suggest that certain sectoral features of an economy may influence energy achievements. These were mainly related to the primary and final energy consumptions and energy poverty, as well as the shares of agriculture, industry and finance in the GVA.

Another important conclusion indicates that the interlinkages with GDP per capita expressed by both the energy achievements and the structural characteristics. The relationships revealed, however, an unexpected result that causes some doubts as to the existence of the U-inverted EKC for the EU-28 states and, instead, suggests an increase in energy tensions in parallel with production level. Thus, the most affluent EU-28 economies need to face severe energy challenges. However, it is still important to enable spillovers concerning energy-saving or renewable resource technology usage to the catching-up countries to avoid repeating the same environment-harming phases of development and make the "time-effect" significant enough to exceed the "gross scale effect" for the benefit of all.

From practical point of view the results suggest a need to synchronize efforts in different dimensions of SD. Politicians must balance all the possible costs and benefits and their decisions should be based on as broad diagnosis as possible. Aggregated approach adopted in the study may be of help in the decision-making process. If policy is focused only on one aspect of energy performance it may lead to unexpected side-effects and, finally, miss its goal of SD. If sectoral policy supports development of a specified branch concerning possible outcomings in one sphere of energy goals, it may appear unfavorable in the other. The practical implication of the findings about indirect character of the relationships is a need to implement horizontal measures of policy aimed at stimulating SD, instead of sectoral specific ones. One must take into consideration that it is necessary to simultaneously create conditions for development of many branches.

Nevertheless, the aggregated approach reveals simultaneously strengths and weaknesses. The mutual interlinkages make it difficult to get robust unequivocal results. The ambiguity of our results suggests a need for further research into the possible interlinkages between different dimensions of SD at a more disaggregated level and to focus more attention on the possible trade-offs and synergies between the detailed goals and structural features. Moreover, a general character of the static diagnosis identifying potential relations makes it valuable to research in-depth the causality in line: economic structure–energy goals. This requires the adopting of a dynamic approach and in-time comparisons. However, it induces some problems to be resolved, such as specification of one measure of structural development that includes numerous sectors, as well as ensuring time-comparability of a synthetic measure of energy performance. Alternatively, the search for interlinkages requires development of quite new methodology of research.

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