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Global Indicators of Sustainable Development: Evaluation of the Influence of the Human Development Index on Consumption and Quality of Energy

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Abstract: The article explores the impact of the quality and volume of energy consumption of the population on the human development index using a sample of a number of countries as an example. The hypothesis concerning the relationship between the amount of energy consumed, the human development index (HDI), and the environment (CO₂ emissions into the atmosphere) has been verified. The study results show that the size and rating of the HDI are influenced by such factors as urbanization growth, gross domestic product (GDP), gross national income (GNI) per capita, the share of “clean” energy consumption by the population and business in total energy consumption, the level of socio-economic development, and R&D expenses. In the course of building the model, the recommendations by the United Nations (UN) and the Organization for Economic Co-operation and Development (OECD) were used. The results show that the volume of energy consumption not only affects the human development index in a particular country, but is also an important factor in determining the level of sustainable development. The results, obtained in the course of the study and described in the article, may be applicable in the practice of research related to the assessment of human development and sustainable development.

Keywords: economic development; energy; human development index; social development; sustainability

1. Introduction

Currently, one of the main drivers of human development is transformation of technology. The Industrial Revolution has brought humankind into an unprecedented increase in wealth. However, it also entailed great divergence, separating the few industrialized societies from the many others that did not industrialize [1–4]. A distinctive feature of the current situation is that, perhaps for the first time in history, many of the technologies behind the current transformations are available everywhere. Technological changes do not occur in a vacuum, but are caused by economic and social processes. This is the result of human activity [3,4]. Government agencies can determine the direction of technological change in such a way as to promote human development. Thus, for example, artificial intelligence can perform tasks instead of people, but, on the other hand, it can restore the

demand for labor by creating new tasks for humans. The resulting positive effect can be aimed at reducing inequality, expanding the opportunities for people from low-income countries, struggling to get an education [5,6].

One of the main indicators characterizing the level and quality of life, and education of the population is the human development index [7–11]. Competition between countries has grown in recent years, and each country wants to become a major player in international economic relations, and play a significant role in the world market [12]. The human development index (HDI) is one of the parameters allowing a country to measure its place in the global world. HDI is an annual indicator of comparing and indicating changes in living standards (through basic indicators of human development characteristics) in different states [13].

Usually, when calculating the HDI, three groups of indicators are taken into account:

- Life Expectancy—measures longevity.
- Literacy rate of the country’s population (average number of years spent on education) and expected duration of education.
- The standard of living, estimated through gross national income (GNI) per capita at purchasing power parity (PPP) in US dollars [14].

Thus, the HDI covers three key aspects of human development: a long and healthy life, access to knowledge, and the standard of living. Modern practice shows that the value of the HDI, according to which a country can be classified as highly developed or underdeveloped, is significantly related to the level and quality of energy consumption. There is a certain rating of countries, according to the HDI. Placement in this rating is relevant to the size (rating) of the index.

2. Literature Review

Recent studies show that the factor determining a country’s specific place in the HDI rating is the type of energy (fuel)—commercial or traditional. Thus, countries with the highest HDI use commercial energy, and countries with the lowest HDI consume traditional fuels [15,16].

Increasing attention is being paid to the study of factors affecting sustainable development. Indeed, the methods and qualities of energy consumption are directly related to this. Countries with higher human development tend to emit more CO₂ emissions per capita, and generally have greater environmental problems [17]. As a consequence, the concept of sustainable consumption at all levels, including at workplace and in private life, has gained significant attention of researchers [18].

Energy intensity is directly dependent on globalization processes and the dynamics of financial development [19]. The expansion of the industrialization policy, the digitalization of technology, are global processes that affect the quality of life and encourage people to move from rural areas to cities in search of high-paying jobs and further education. At the same time, they have more permanent access to electricity. A large number of people in urban centers leads to greater use of energy.

In rural areas, lack of access to electricity can adversely affect HDI values. In areas where electricity is more affordable, it is becoming easier to provide better education and health care. Energy consumption also tends to have a significant positive impact on research and development (R&D) expenditures [20]. In addition, electricity in rural homes improves the quality of life by reducing the need to burn more harmful fuels. In general, wider access to electricity and, consequently, wider use of energy in countries can explain high HDI values [21,22].

Statistics show that, as a rule, developed countries have high values of the human development index, which should provide citizens with resources, including energy resources. At the same time, for developing countries with medium and low levels of development, the situation is the opposite [23]. There is little research that explores the impact of the quality and volume of energy consumption of the population on the human development index, using a sample of a number of countries as an example.

Almost all case studies focus on the relationship between indicators of economic development and energy consumption. The methodology of case studies has traditionally been quantitative, where little

attention has been paid to the connections between the parameters of the quality of life of a society and energy consumption. This study sought to eliminate the above gap. The proposed model will be based on an atypical indicator of economic research—the human development index. Based on it, through a system of simultaneous equations, relationships will be revealed between economic development, the energy issue, the environment (CO₂ emissions into the atmosphere), and human capital.

The research topics addressed in this study are:

- determine the purpose and structure of using the HDI;
- study the relationship between the amount of energy consumed, the HDI, and the environment (CO₂ emissions into the atmosphere);
- analyze the contribution of renewable energy sources to improving economic conditions and the level of sustainable development.

3. Methods

3.1. Research Design

To study the relationship between the amount of energy consumed, the HDI, and the environment (CO₂ emissions into the atmosphere), the three-stage least squares (3SLS) method was used in the work. This method reveals the causes and describes the relationship between human development, energy consumption, the level and share of renewable energy use, the volume of government measures to improve the environment and reduce harmful emissions into the atmosphere. The general approach of 3SLS takes into account the following aspects:

- features of each state included in the sample of countries; at the same time tracing differences between them, which are constant over time;
- endogenous variables problem;
- error correlation problems between equations that make up the model.

It is worth noting that the 3SLS method is simpler compared to the usual two-stage least squares method (TSLS, 2SLS) and has several advantages. Thus, according to the ordinary least squares method, the following is implemented:

Step 1. The dependence of endogenous variables on all exogenous ones are estimated (the unlimited reduced form is actually estimated).

Step 2. The structural form of the model is evaluated, where instead of endogenous variables, estimates obtained at Step 1 are used.

In the two-step least-squares method, in fact, each equation of the structural form is evaluated independently of other equations, i.e., the possible relationship of random errors of the equations of the structural form to each other is not taken into account. In the three-step least-squares method (3SLS), the Step 1 and Step 2 coincide with the 2SLS and the following is added:

Step 3. Based on the 2SLS estimates of the residuals of the structural equations, an estimate of the covariance matrix of the random error vector of the system is obtained, and with its help, a new estimate of the coefficients is achieved using the generalized least squares method. If there are correlations between the equations, the 3SLS estimates should theoretically be better than the 2SLS estimates [24–27].

3.2. Data Analysis

To solve the task of studying the relationship between the HDI, the amount of energy consumption and the level of sustainable development within the state, the authors use the method of regression analysis. As an instrument, the authors choose a model consisting of three equations, each of which gives an estimate and describes each studied parameter. This model includes recommendations, methodologies, methods for identifying the relationships between statistical data related to issues related to energy consumption and the HDI developed by the Organization for

Economic Co-operation and Development (OECD) and the United Nations (UN), which are described in annual reports on sustainable development goals, indices, and indicators of human development (statistical information) [13,23]. The empirical basis of this study is a model in which the relationship between environmental pollution, energy sources, and economic development through behavioral equations is shown:

$$\text{HDI}_{it} = \alpha_i + \alpha_1 * \text{Kpc}_{it} + \alpha_2 * \text{Pop}_{it} + \alpha_3 * \text{HC}_{it} + \alpha_4 * \text{LE}_{it} + \alpha_5 * \text{RNE}_{it} + \alpha_6 * \text{CO}_2_{it} + E_{it} \quad (1)$$

where,

HDI—human development index;

Kpc—main factors of capital production;

Pop—major population factors;

$\alpha_1 \dots \alpha_n$ —statistical determinants (constant expected parameters);

HC—human capital;

LE—life expectancy;

CO₂—CO₂ pollution;

E—energy consumption.

In detail, the variables in the composition of equation 1, in the corresponding unit measurements, are disclosed in Table 1. RNE—renewable energy consumption: share of renewable energy (in %) in total consumption. This equation defines the factors that explain the level of sustainable development of the country.

HDI is used as an indicator of the level of sustainable development of each country. The equation also includes the main factors of capital production (Kpc) and population (Pop) in order to determine the stage of development of the country, the expected statistical positive ($\alpha_1 > 0$) or negative ($\alpha_2 < 0$), respectively.

The conceptual basis is that a decrease in per capita income has a negative impact on HDI amid population growth. Theory of endogenous growth demonstrates that human capital (HC) and health standards, given the value of life expectancy of a person (LE) are basic institutions, the development of which creates a positive effect in any economy, which in the case of an equation is expressed as $\alpha_3 > 0$ and $\alpha_4 > 0$ [28–30].

It is worth paying attention to the assessment of the impact of energy consumption (E) on the sustainable development index ($\alpha_5 > 0$). At the same time, the CO₂ parameter (CO₂ pollution) is expected to have a negative impact on the level of development ($\alpha_6 < 0$), due to the negative impact of pollutant emissions on living standards. Permanent determinants ($\alpha_1 \dots \alpha_n$) represent parameters (the so-called “effects”, terminology in OECD, UN reports), country-specific that are constant over time. This is about the size of the country, natural resources, location, religion [28–30].

Equation (2) of the system demonstrates the parameters of energy consumption in the form:

$$\text{RNE}_{it} = \beta_i + \beta_1 * \text{HDI}_{it} + \beta_2 * \text{R\&D}_{it} + \beta_3 * \text{HK}_{it} + \beta_4 * \text{NUCE}_{it} + \beta_5 * \text{PFE}_{it} + \beta_6 * \text{EnDep}_{it} + E_{it} \quad (2)$$

where:

RNE—renewable energy consumption: share of renewable energy (in %) in total consumption

$\beta_1 \dots \beta_i$ —statistical determinants (constant expected parameters);

HDI—Human development index;

R&D—Total research and development costs, in % of GDP;

NUCE—nuclear energy consumption: share of nuclear energy (in %) of total consumption;

PFE—energy price;

EnDep—level of energy dependence on imports (share of imported energy in total consumption);

E—energy consumption

In detail, the variables in the composition of Equation (2), in the corresponding unit measurements, are disclosed in Table 1. In Equation (2), the authors assume that energy consumption depends on the level of human development (HDI) and the “feedback” effect. Thus, it can be said that more developed countries will invest more in promoting renewable energy, so it is expected that $\beta_1 > 0$. It is also assumed that technology development costs are important for energy use, while also $\beta_2 > 0$.

Increasing R&D costs is a prerequisite for the development of environmentally friendly energy projects based on advanced technologies. This is due to the fact that a high human development level and knowledge acquisition are important for the implementation of new ecological energy sources, with $\beta_3 > 0$ [31–36].

Nuclear energy consumption (NUCE) will stimulate the usage of other renewable sources. This will negatively impact the NUCE and thus β_4 will be negative.

PFE—energy price, might encourage the usage of renewable sources by substitution effect, with positive β_5 .

EnDep—energy dependence on imports (the part of imported energy in overall consumption). Imported energy dependence (mostly fossil energy) can stimulate states to use new, clean energy ($\beta_6 > 0$) to decrease cost as well as atmospheric pollution.

Constant expected parameters ($\beta_1 \dots \beta_i$) show distinctive and constant features of states [31–34].

Equation (3) of the system provides an opportunity to assess the need of modern societies (especially at advanced levels of development) to increase economic activity using clean energy sources. An indicator to make such an estimate is the frequency of CO₂ emissions.

This indicator can be calculated as follows:

$$\text{CO}_2 = \gamma_1 + \gamma_1 * \text{HDI}_{it} + \gamma_2 * \text{HDI}_{it}^2 + \gamma_3 * \text{TENC}_{it} + \gamma_4 * \text{RNE}_{it} + \gamma_5 * \text{HC}_{it} + E_{it} \quad (3)$$

where:

$\gamma_1 \dots \gamma_n$ —statistical determinants (constant expected parameters)

HDI—human development index;

TENC—actual energy consumption per capita

RNE—renewable energy consumption: share of renewable energy (in %) in total consumption

HC—human capital;

E—energy consumption

In Equation (3), the authors associate CO₂ emissions with the level of development and its square in order to test the hypothesis of the environmental Kuznets curve (EKC) about the environment in the form of a reverse U-formed relation between ecological reduction and development of the economy. The EKC states that ecological conditions worsen with the improvement of the economy. However, this trend overturns at a specific stage of development and thus ecological situation improves with economic advance [37]. Thus, at the development level, there is a threshold point, the achievement of which suggests that the country is taking measures to reduce air pollution. To confirm the EKC hypothesis, the authors expect that $\gamma_1 > 0$ and $\gamma_2 < 0$ both are statistically significant.

It can be said that with the rise of overall energy consumption (TENC), there will also be an increase in CO₂ emissions, as a large share of the consumed energy comes from fossil fuels, with $\gamma_3 > 0$. The use of ecological renewable energy sources (RNE) leads to the reduction in air pollution ($\gamma_4 < 0$).

Lastly, education will help diminish air pollution since an educated individual is more aware of air pollution, and qualified workforce can contribute to clean energy development, thus, $\gamma_5 < 0$. Each state has its own specific and constant parameters (γ_i) [35–39]. Three equations together represent a system of relations between economic variables, energy policies and the aim to reduce pollution in relation to sustainable development.

Key ideas (results) of applying the model in practice:

- Renewable energy along with other significant factors will contribute to sustainable economic development (Equation (1)).
- The development of R&D projects in the context of strengthening human capital will contribute to the scaling of clean energy technologies (Equation (2)).
- Macro-level alternative energy strategies to reduce environmental pollution will directly depend on the degree of socio-economic development of the state (Equation (3)).

The main model variables, which are included in each equation, are: HDI, renewable energy consumption (RNE) and CO₂ emissions, which, in general, can be considered as endogenous parameters in the system of equations (model). The model is based on the 3SLS method, which allows one to control the endogeneity of variables and takes into account data correlation errors in the equations. Table 1 describes in more detail the variables that make up all three equations of the system. There are fifteen variables in total: one dependent (the HDI of each OECD country selected for the purposes of a survey expressed as a score from 1 to 100) and fourteen independent variables representing socio-economic parameters of the OECD countries selected for the survey (Table 1).

Table 1. Variables of the model of the relationship between energy consumption, HDI, and the level of sustainable development of state.

Variable Designation	Variable Definition	Unit of Measurement	Data Source	
HDI	Human development index, an index with a scale from 0 to 100	Scale [0; 100]	United Nations Development Program—Human Development Reports (April 2017)	
HK ₁	Average period of study	Years		
K _{pc}	Gross fixed capital formation per capita	million US dollars in 2017 prices	Annual macro-economic (AMECO) database (April 2017)	
Pop	Total population	thousands of people		
LE	Life expectancy	Years	Eurostat database (April 2017)	
HK ₂	Population aged 15–64 with higher education	%		
R&D	Total research and development costs, in % of gross domestic product (GDP)	%		
RNE _{share}	Renewable energy consumption: share of renewable energy (in %) in total consumption	%		
NUCE	Nuclear energy consumption: share of nuclear energy (in %) in total consumption	%		
EnDep	Energy dependence: the ratio of net imports to the sum of gross domestic energy consumption and marine bunkers	%		
TENC	Actual energy consumption per capita	thousand tons of oil equivalent		
CO _{2pc}	Greenhouse gas (GHG) emissions per capita	tons of CO ₂ equivalent per capita		
PFE _{oil}	Crude oil price—OECD (The Organisation for Economic Co-operation and Development) countries	US \$/million BTU (British thermal unit)		British Petroleum (BP) Statistical Review of World Energy June 2016 (April 2017)
PFE _{gas}	Natural gas price, average import price, Germany	US \$/million BTU (British thermal unit)		
PFE _{coal}	Coal Price, Northwest Europe	USD per ton		

Source: [40–44].

Let us pay attention to the variables describing education:

- Average number of years at school (HK₁)
- Percentage of the population who have received the bachelor's degree (HK₂).
- Life Expectancy (LE) is a parameter to assess the quality of public health.

The impact of energy prices is traditionally assessed through three indicators: oil, gas, and coal prices. The authors note that the oil price demonstrates a higher statistical significance in this

approach [45–51]. To build a model (solve a system of equations), a sample of 336 observations was used for a group of 28 OECD countries, covering the period from 2006 to 2017, where the HDI has the minimum value of 75 and the maximum value of 93 (Table 2).

Table 2. Summary statistics of variables used for the model of the relationship between energy consumption, HDI, and the level of sustainable development of state.

Variable	Observations, Quantity	Mean	Standard Deviation	Min	Max
HDI	336	85.63	4.11	75	93
HK ₁	336	11.19	1.22	7	13.3
K _{pc}	336	6.96	2.85	1.93	19.18
Pop	336	17,929.1	22,678.8	401.16	81,687
LE	336	78.55	3.15	70.6	83.3
HK ₂	336	22.78	7.32	8.7	39.6
R&D	336	1.48	0.88	0.34	3.75
RNE _{share}	336	15.46	11.23	0.1	53.9
NUCE	336	15.38	20.18	0	89.58
EnDep	336	55.91	27.68	−49.8	104.1
TENC	336	2.49	1.4	0.94	9.61
CO _{2pc}	336	10.59	4.31	4.98	31.18
PFE _{oil}	336	13.28	4.24	6.27	18.82
PFE _{gas}	336	8.5	2.12	4.3	11.6
PFE _{coal}	336	85.34	25.37	56.64	147.67

Source: [4].

4. Results

The results of the regression analysis are obtained using the data of the statistical sample using the 3SLS method (Tables 1 and 2, section Data Analysis). The results (shown in the Table 3) allow identifying the relationship between the studied parameters: energy consumption, HDI, and the level of sustainable development of the state.

Table 3. The results of the study, 3SLS (three-stage least squares) method, 28 OECD countries, 2006–2017.

Variable	Dependent Variable HDI	Dependent Variable RNE _{share}	Dependent Variable lnCO _{2pc}
constant	74.59 (2.43) [0.015] **	−141.75 (−13.86) [0.00] ***	−19.55 (−5.90) [0.00] ***
lnK _{pc}	0.75 (3.34) [0.001] ***		
lnPop	−4.12 (−1.62) [0.106] *		
HK ₁	0.61 (6.07) [0.00] ***		−0.08 (−6.08) [0.00] ***
HK ₂		0.13 (3.57) [0.000] ***	
lnLE	12.19 (1.12) [0.26]		
RNE _{share}	0.31 (3.03) [0.002] ***		−0.01 (−2.92) [0.003] ***
lnCO _{2pc}	−1.26 (−0.66) [0.51]		
lnTENC _{pc}			0.59 (9.00) [0.00] ***
HDI		1.54 (12.04) [0.000] ***	0.52 (6.54) [0.000] ***
HDI ²			−0.003 (−6.23) [0.000] ***

Table 3. Cont.

Variable	Dependent Variable HDI	Dependent Variable RNE _{share}	Dependent Variable lnCO _{2pc}
R&D		1.78 (3.19) [0.001] ***	
NUCE		0.01 (0.89) [0.374]	
lnPFE _{oil}		0.18 (0.87) [0.382]	
EnDep		0.001 (0.12) [0.907]	
D2008	0.63 (4.37) [0.000] ***	-1.58 (-4.71) [0.000] ***	-0.006 (-0.55) [0.54]
N° obs.	336	336	336
R ² 1	0.97	0.97	0.98
RMSE	0.66	1.68	0.047
Chi ²	12,409.52 [0.000] ***	15,499.56 [0.000] ***	19,510.87 [0.00]
Hausman test	chi2(33) = 69.35 [0.0002]	chi2(34) = 12.862732 [0.99961738]	chi2(32) = 6.47 [0.99]
AR test	F (1, 27) = 12.19 [0.0017]	F (1, 27) = 39.479 [0.0000]	F (1, 27) = 41.83 [0.00]

Source: OECD data, partially authors' calculations (Endogenous variables: RNE_{share}, HDI, HDI₂, and lnCO_{2pc}. Exogenous variables: ln Pop, lnK_{pc}, HK₁, HK₂, EnDep, lnLE, R&D, NUCE, lnPFE_{oil}, lnTENC_{pc}, and other variables, in regressions. Notes: the figures in brackets are z-relations, and the figures in square brackets—*p*-values $p > |z|$. Chi²—statistically significant coefficients. The AR test employs Wooldridge statistics for idiosyncratic errors autocorrelation in panel data (Wooldridge, 2002; Drukker, 2003). ***, **, * mean statistically significant coefficients at a significance level 1%, 5%, and 10%.) [52].

Let us briefly describe the performance indicators shown in Table 3.

Regarding the main variables—structural elements of the system of equations (model):

The share of energy has the anticipated positive effect on the development, with high statistical significance of 1%. It is anticipated that (with everything else being equal) a rise in this source usage by one percentage point, there will be a rise in development by 0.31 points. The use of ecological energy (with low carbon emissions) enhances sustainable development. Lastly, CO₂ emissions per capita, because of fossil energy consumption, negatively impact development; however, without any significant statistical findings. Thus, one cannot accurately evaluate the negative impact of carbon emissions on development [53,54].

Overall, the reversion outcomes are suitable due to statistically significant coefficients. All coefficients of backward dependent variables are statistically significant at the highest level of 1%, thus, the model's dynamism is justified on the basis of the principle of fractional adjustment.

Regarding Equation (1) of the model:

The coefficients as a whole are statistically significant and have the expected characteristics, with the exception of the variables CO₂ and population. As in Table 3, it is impossible to statistically confirm the expected harmful effects of environmental pollution on the level of development.

Life expectancy is currently statistically significant at 1%, which indicates that in the short term, an increase in life expectancy of one percent is the reason for the increase in the level of development by 0.0024 points (0.0038 is a long-term effect) *ceteris paribus*. According to Table 3, the data indicate that 63% of the changes in the HDI can be adjusted to the desired or optimal level during the same period, which is a fairly quick achievement of the effects.

Concerning the model's Equation (2):

As shown in the tables, the education (the part of population with higher education), R&D and economic development positively impact the energy consumption, and all have statistically significant values at normal probability levels. Particularly, in a short run, with a rise in higher education by 1 percentage point, there will be an increase in renewable energy consumption by 0.065 percentage points, *ceteris paribus*. Long-run effect is higher and states 0.32 percentage points. The short-run

effect of R&D is 0.52 percentage points and a long-run—2.57 pp on renewable energy consumption, however, it is statistically significant only at 10%. The impact of development on the increase in the consumption of renewable energy is 0.30 pp in the short run and 1.45 pp in the long term and statistically significant at 1%. Again, as in static model, one cannot give strong evidence that nuclear energy and the dependence on imported energy are important factors for determining energy consumption, as long as their coefficients are not of statistical significance. The oil price loses its statistical significance as short-run stimulus; besides, there is a rather slow adjustment rate, only 20% change in renewable energy share is adjusted to the expected level at the considered period [51,52].

Concerning the model's Equation (3):

The computation (statistically significant impact of education on decreasing CO₂ emissions) confirms that education is necessary for awareness of the need for atmospheric quality. In the short run, an annual increase in school attendance leads to about 4% decrease in CO₂ emissions (6.3% is a long-run effect), *ceteris paribus*. Moreover, with a high energy consumption, there is as well a high air pollution with a short-run elasticity of 0.5% and a long-run exposure of 0.714%. The HDI's positive impact and the negative impact of HDI's square value confirm the U-formed reverse relation between the development level and CO₂ emissions with a short-run HDI threshold point of 81.64 (scale from 0 to 100). It should be noted that a change in favor of renewable energy in CO₂ emissions has a less negative impact on the model's effective value. Besides, about 70% of the actual change of CO₂ emissions can be amended to certain level, presenting a quick set up [53,54].

The authors believe that in the long term, the HDI can be transformed and applied in its expanded version with the inclusion of an energy component. Implementation in practical use will be achieved by applying the index when tracking the status of clusters of states with similar basic parameters. Such groups of countries can be determined based on geographic location (regions) or essential characteristics (typology of countries). However, limitation here might be a mixing of resources, intermediate and final results in the model. A similar mix is also observed in the HDI, however, it is still a measure applicable worldwide. A modified HDI will focus on development results, where also some of the index indicators will be "twofold": they can be considered both the result of certain processes and the main factor for further improvements in other measurements. The list of indicators for these purposes can be expanded, but the issue of international comparability significantly reduces the potential list.

5. Discussion

Next, the authors analyze the opinions and points of view of scientists regarding the general approach and the 3SLS method used in the study. First of all, the authors note that the Hausman test taken into account in the study confirms the hypothesis that the 3SLS method displays estimates that are more representative than the 2SLS method, which is true for all three equations in the system [25,26]. Most scientists agree that there are three main approaches to studying the impact of human and nationwide economic development on changing the approach to the use and consumption of energy resources [27]. In general, these approaches provide a better understanding of the impact of expenditures on energy consumption and describe economic growth [44,52].

Currently, international discourse in the field of sustainable development covers issues related to the rationale that without increasing the level of human capital, the distribution and redistribution of resources [55], the effective implementation of renewable energy sources is not practically feasible. This is necessary in order to be able to finance projects that provide innovative ways to produce clean energy. An increase in the share of production and consumption of "clean" energy positively affects the growth of sustainable development. However, at the same time, there is a need to study the cause-effect relationships between these aspects [11,24,32].

A growing number of scientists studying sustainable development issues have come to the conclusion that renewable energy sources contribute to higher economic development without

environmental degradation, and justify the need for measures in this direction. It is important to focus on the development of new energy strategies, policies, measures to improve the environment [10,31,45–50].

The common idea is that energy costs have been comparably constant for years and are very much alike between regions and large states. Moreover, a gradual GDP growth slows down energy consumption and results in decreased energy prices until the balance is achieved again. The increase in energy costs leads to a decrease in its consumption, respectively [21].

Many note that the relatively high energy prices create a favorable environment for the growth of energy production, which further reduces demand and, ultimately, cost. Moreover, energy policies are usually carried out at the national or regional level, and not globally. In developed countries, for example, there is a grid planning system in which the optimal energy consumption for a country is modeled on the basis of a number of factors, such as energy and economic benefits [41,48].

At the same time, another group of researchers is inclined to believe that a high level of development of human capital, a significant share of educated people, people with higher education and the use of renewable energy reduce CO₂ emissions. Thus, it is confirmed that an educated population is aware of the need to reduce air pollution and start using “clean energy”. Overall, energy consumption leads to a rise in CO₂ emissions, since the energy is mostly fossil [48,50].

According to the methodology of the United Nations Economic Commission for Europe, the standard of living of the population can be estimated through the parameters of total government debt as a percentage of GDP and energy use (kg of oil equivalent) per \$ 1000 of GDP (PPP constant 2005). The disadvantage of this approach is that it does not take into account the fact that energy efficiency can be associated with geography. In addition, CO₂ emissions are not included in the assessment of the accompanying economic processes, since they are considered at the place of production, not consumption, thus, this assessment does not objectively reflect the quality of life of the population.

Three traditional dimensions of the HDI (long and healthy life, high-quality education, and income that ensures decent living) reflect the basis of the life of society. Nevertheless, it can be assumed that for people the possibility of living in an unpolluted environment is equally important. The assumption has practical implications—in 1995, the Republic of Armenia, with the support of UNDP, has begun to use the HDI that includes an environmental component. Thus, there is a formed request of a number of states to expand indicators within the index. However, when new indicators are included, it is necessary to separate the stimulating environmental factors reflecting positive characteristics and the stimulating environmental factors reflecting negative phenomena. In the case of stimulating factors, a direct measurement scale will be applied, i.e., an increase in stimulating parameters improves the HDI, whereas in the case of de-stimulating factors, an inverse measurement scale, i.e., an increase in discouraging indicators, lowers the HDI.

6. Conclusions

The article analyzes the relationship between the level of sustainable development, energy consumption, and the environment (air pollution). The degree of influence of these factors on the HDI is estimated. The relationship between these parameters was investigated using a system model of variables according to the 3SLS method. The latter simultaneously takes into account the problem of endogeneity and the relationships between variables (sustainable development, energy consumption and ecology) through correlation of errors between the equations. The results of testing the model revealed a relationship between them, a feedback effect, and the ability to predict future development trends.

Regarding the parameter of the system model describing the level of CO₂ emissions, it is characterized by a non-linear relationship between the level of pollution and economic development. Most of the OECD countries examined in the sample, presented in the Data Analysis section, reached the threshold level of sustainable development (the average score on the graphs is 86.4 on a scale from 0 to 100). To reach this threshold level, the study showed that countries in the sample take measures aimed at reducing atmospheric pollution.

The hypothesis is confirmed that the threshold level, when it will be possible to say that the state is developing steadily, depends on its understanding of the need to implement and take measures to improve the environment and protect the atmosphere. As measures might be the development of new sources of renewable “clean” energy, strategies for “smart” energy consumption by the population and business. Within large energy businesses—the introduction of models of “smart distribution networks”, green tariffs that stimulate the generation and use of “clean” energy and so forth.

The authors conclude that the level of development of human resources/capital contributes to the achievement of the above strategies and models for optimizing energy consumption and using more environmentally friendly sources. The level of development of human resources/capital can be characterized by indicators such as HDI, share of population with higher education, the ratio of R&D expenditures to GDP. In the course of the study, a relation was found between energy consumption and sustainable development with a “feedback effect”; the necessity of knowledge and innovation in energy field was substantiated. In general, it is worth noting that the article is of a general scientific and universal nature, the obtained results can be applied in the study of the influence of energy consumption on the level of human development and vice versa, as well as in the practice of applying energy-optimizing and sustainable development strategies.

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