TRANSITIONING TO GREEN ECONOMY: SOLAR AND WIND ENERGY OVERTAKING HYDROPOWER - EVIDENCE FROM 20 SELECTED COUNTRIES

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ARTICLE INFORMATION	ABSTRACT
Volume: 1 **Issue: 9** **DOI:https://doi.org/10.55439/INSURE/vol1_iss9/a12**	The purpose of this research is to make a deeper investigation into the impact of Renewable Energy consumption and CO2 emissions. Unlike in previous studies, types of renewable sources of energy in this research were depleted and considered separately. Namely, the top 20 most wind and solar-powered countries were selected and the research was made on how these two types of renewable energies assist in the CO2 mitigation process by running panel data regression with 3 control variables: wind and solar energy taken as a single control variable, hydropower and GDP per capita for the period 2000-2018. The findings suggest, that a 1% increase in the usage of wind and solar power for electricity generation decreases CO2 emissions by 0.133 metric tons per capita, similarly a 1% increase in hydroelectric sources for electricity generation decrease CO2 emissions by 0.028metric tons per capita. Meanwhile, a 1 % rise in GDP per capita increases CO2 output by 2.635 metric tons per capita.
KEYWORDS	*Renewable energy, CO2 emissions, GDP, solar energy, wind energy*

Introduction (Кириш/Введение)

While 13% of the world population does not have access to electricity that can provide very basic lighting, and charge a phone or power a radio for 4 hours per day, per capita consumption of it varies more than 100-fold across the world [12]. An average American citizen consumes more than ten times the energy of the average Indian, 45 times that of those who live in Brazil, and three times more than China. Since energy is the backbone of an economy, and its contribution to economic growth is selfcontradictory the question how should countries with different levels of GDP and CO2 emissions approach the issue of CO2 reduction has been the focus of scholarly interest for the past 20 years. The question who is responsible for global climate change arises many more questions than answers. Should countries emitting the most CO2 today or the ones which emit the most CO2 per person or the countries which emitted the most in total reduce its output?

Although main CO2 emitters are developed countries, the negative influence of greenhouse gases is seen in low-income agrarian nations. Since agriculture is a major activity in this region at the economic and social levels, it makes this industry vulnerable to climate change. [6]Food security, is however, threatened by a rising speed of climate change, growth in world population and income. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changing precipitation patterns increase the possibility of short-run crop failures and long-run production downturns. In spite of the gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security.

Populations in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected [4]. Considering the mentioned above, the purpose of research is to identify, whether all the countries can follow SDGs, and think of CO2 mitigation. Not all the countries can mitigate CO2 emissions without any threat to economic development, and even more, the real threat is targeted at developing countries, where agriculture is the main source of income. Meanwhile, the greatest numbers of CO2 emissions are displayed by industrialized countries.

All power production plants affect the environment and the ecosystems on Earth. Solar and wind systems are becoming more popular worldwide and are no longer specific to coastal, mountainous, desert or arid regions. So, the significance of studying the ecological impact is essential for the sustainability of these systems. This impact on the environment varies according to the level of development of a country and its geographical location. Relying upon the abovementioned, I explore the impact of greenhouse gas emissions, per capita GDP, the share of hydropower for electricity generation, share of solar and wind power energy for electricity generation for the top 20 most solar and wind energy using countries. The empirical results show that while GDP has a positive effect on CO2 emissions, hydropower and solar-wind based energy for electricity generation have negative effects.

LITERATURE REVIEW (Адабиётлар шархи/Обзор литературы)

Extensive investigations over the topic of RE consumption and economic growth, FDI, population growth, nuclear energy and urbanization have been carried out since sustainable development has been on the international agenda. Literature studying RE nexus CO2 can be divided into two main strands:

EKC (Environmental Kuznets Curve) emissions and economic growth.

EKC was first offered by Grossman and Krueger [5] in 1991 which made a major contribution to the analyses of economic growth and environmental pollution. As a result, a great number of researchers started to analyze the validity of it using a number of variables and data sets by different econometric models and provided vague empirical outputs concerning the validity of EKC hypothesis.

For instance, [7] studied the effects of energy consumption, economic growth, RE, finance markets developments, trade openness, and urbanization growth on CO_2 emissions. To do that they used the Pooled Mean Group approach. Further, a Granger Causality test was conducted in the EKC model with a data set of 25 African countries. The period 1985–2015 was tested. The outcome of the analyses was as following: RE consumption and trade openness decreased CO_2 emissions, thus supporting the EKC hypothesis for the selected African countries within the given period.

The presence of bidirectional causality between economic growth and financial development and CO_2 emissions were indicated by Granger's causality outputs [14] through the observed results show that non-RE consumption increases CO_2 emissions, whereas RE consumption decreases CO_2 emissions. Along with that, they find the existence of an environmental Kuznets curve between urbanization and CO_2 emissions, implying that at higher levels of urbanization, the environmental impact decreases. Besides that [11]in his research over Turkey for the period 1974-2014 also supports the significance EKC for that country which establishes the link between EKC and GDP per capita. His findings conclude that the turning point of GDP per capita should be between 13523–14077 US Dollars so that it could reduce environmental pollution. [1] also supported EKC.

In contrast, [17] fails to validate EKC hypothesis. In his panel cointegration analysis with a set of robustness tests to assess the short and long-run impacts of RE on CO_2 emissions, as well as the Kuznets Environmental Curve hypothesis for 25 selected African countries, over the period 1980-2012 he finds no evidence of a total validation of EKC predictions. Exploring the relationships among per capita carbon dioxide (CO_2) emissions, gross domestic product (GDP), renewable, non-RE production and foreign trade for China covering the period 1980-2014 [3] ,[2] find that there is a long-run relationship among those variables. Moreover, they find that China does not have the EKC of CO_2 emissions under the influence of economic growth, non-RE production and foreign trade. The addition of RE production variable, validates the existence of the inverted U-shaped EKC hypothesis in the long-run.

Investigation of the causal relationship between economic growth and RE consumption in BRICS countries for the period 1971 – 2010 was carried out by [13] concluding that there does exist Granger Causality test between economic growth and RE consumption, suggesting a feedback hypothesis clarifying the role of RE in economic growth. Meanwhile, [8] employ the 3SLS model to conduct an empirical study on the relations among real output, RE consumption, and CO_2 emissions of BRICS countries (except Russia) in 1999–2014. By using ARDL bounds testing approach, Gregory-Hansen and Hatemi - J cointegration tests for Turkey from 1974 to 2014 [11] investigated the short and long-run dynamic relationship between per capita GDP, per capita carbon dioxide (CO_2) emissions, financial development, per capita total RE consumption, hydropower consumption, alternative energy consumption and urbanization. The effects of stock market growth and RE use on CO_2 emissions was studied by providing evidence from G20 countries by [10]

A Granger causality test and panel cointegration techniques are used to investigate the dynamic causal links between per capita RE consumption, real GDP, agricultural value-added, and CO_2 emissions for a panel of five North Africa countries between 1980 and 2011 by [9]. Granger causality tests reveal bidirectional causality between CO_2 emissions and agricultural in the short run, as well as unidirectional causality from agriculture to GDP, GDP to RE consumption, and RE consumption to agriculture. In the long run, there is bidirectional causality between agricultural and CO_2 emissions; a unidirectional causality runs from RE to agriculture and emissions, as well as from out-put to agriculture and emissions.

According to long-run parameter estimations, increasing GDP or RE consumption (including combustible and waste) increases CO_2 emissions, whereas increasing agricultural value-added reduces CO_2 emissions.

METHODOLOGY (Методология/Методология)

Data description

In this study the dataset consists of one dependent (CO_2 emissions, in metric tons per capita) and three independent variables: Solar and Wind Energy in electricity generation, as a % share of total electricity production, Hydropower -Electricity production from hydroelectric sources (% of total) and GDP per capita based on purchasing power parity (PPP) in constant 2017 international dollars.

Observations included top 20 most solar and wind energy consuming countries for generation of electricity. These are Australia, Belgium, Brazil, Chile, China, France, Germany, Italy, Japan, Mexico, Netherlands, New Zealand, Poland, Portugal, Romania, Spain, Sweden, Turkey, United Kingdom, and the United States. Due to the availability of data an 18-year period, (2000-2018) was taken to investigate the dependence of CO_2 on the three variables mentioned above.

As the GDP per capita based on PPP was available for the period 2000-2016, this data was balanced by selecting mean of the data for each country.

The output variable CO_2 is widely researched among scholars. In extant literature, different types of renewables are put under a single variable and its effect is studied accordingly. This research depletes the renewables into two main categories and analyses the impact of each separately. This decision has been done for a few reasons: first of all hydropower has historically been used on a large scale and together with nuclear makes up about 10% of total energy use [12] The potential of the hydropower is almost totally employed.

Moreover, most areas that are densely populated and are in greater need for energy, feel more need water resources for its primary use. Some developing countries undergo water shortage and this shortage is expected to rise with time [16].

Data description

Data for CO_2 in metric tons per capita, Share of hydropower(H) and GDP per capita have been obtained from the World Bank, while the Share of Wind and Solar Energy in electricity generation was taken from www.enerdata.net. The Figure1 provides data on top countries which use Wind and Solar (WS) energy for electricity generation.

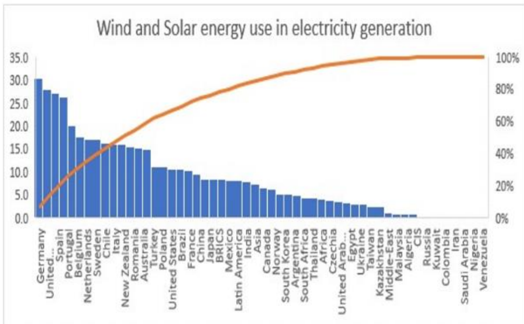

Figure 1.Wind and Solar Energy Use in Electricity Generation as % change between2000-2020 www.enerdata.net

The data to identify most WS energy using countries was used by the % change of WS energy in electricity production throughout 2000-2020. As it can be seen from the chart, the most WS energy consuming country is Germany with 30.5 % increase in share of electricity production, followed by the United Kingdom with 28% change and Spain. The list is closed by Saudi Arabia, Nigeria and Venezuela with 0.1 % changes in the observed period.

Using the data on this graph, 20 top solar and Wind energy using countries have been selected, while the rest neglected as it would have been difficult to evaluate the contribution to CO_2 mitigation of solar and wind power, the share of which was close to 0%.

In Figure 2, we can see if the change in WS use in electricity generation throughout 2000-2020 was similar to the WS use in electricity generation as of 2020. The outcome of the data has shown, that the top countries remained unchanged – Germany, Spain and the UK with around 30% of the share, while the closing list countries used about 10% of WS in the total production of electricity. Figure 3 visualizes the data for CO_2 emissions for 20 selected countries between 2000-2018.

As can be seen from the graph, the greatest emitters per capita are the UK, USA and Australia with around 18-20 mt tons per capita, whereas Germany produced under 10 mt tons.

This is due to great efforts done by the German government to shift into green economy. The lowest CO_2 emitters per capita are Brazil and Turkey, with just around 2-5 mt tons. An association test for a panel data set of 20 countries with 3 independent and 1 dependent variable was made, indicated that we should reject the null hypothesis (assumption that rows and columns of the table are independent) and accept alternative hypothesis Ha, that there is a link between the rows and columns of the table.

Table 1 gives the data for R and adjusted R and F test. Adjusted R squared shows the percentage which can be predicted by this model. In this model, only 43,6% of the output can be predicted by the given independent variables.

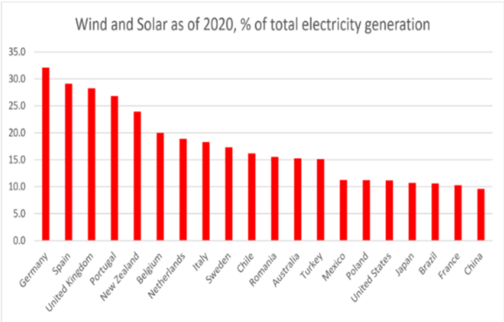

Figure 2. Wind & Solar Energy as of 2020, % of total electricity generation. (www.enerdata.net)

P-value obtained in this regression is less than 0.0001, which is enough to conclude that the results are valid. After running a panel data analyses, the model obtained is shown below

$$yit = -0.133x1it + 2.635x2it - 0.028x3it + \varepsilon it \qquad \text{Equation 1}$$

The subscripts i and y in equation *(1)* stand for a country and years accordingly, y_{it} is the amount of CO2 emissions per capita in metric tons, x1 – share of Wind and Solar energy use for electricity generation in %, x2 – GDP international logged naturally, x3 – share of Hydroelectric sources for electricity generation in % of the total and ε_{it} is the residual. The deviations of predicted results from the real ones are shown in the residuals column. The list of residuals is provided in the Appendix. When we add up all the residuals, the sum we get is equal to 0. According to our equation, we have the following results:

A 1% increase in the usage of Wind and Solar power for electricity generation decreases CO2 per capita emissions by 0.133 metric tons per capita, similarly a 1% increase in hydroelectric sources for electricity generation decrease CO2 emissions per capita by 0.028metric tons. Meanwhile, a 1 % rise in GDP per capita increases CO2 output by 2.635 metric tons per capita.

The given output proves out hypothesis that solar and wind energy, together with hydropower decrease emissions. There are many other factors in fact which may decrease the amount of CO2 emissions, like urbanization and use nuclear power plants. Obviously, urbanization can also be investigated separately by analyzing its impact on the environment.

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$$yit = -0.133x1it + 2.635x2it - 0.028x3it + \varepsilon it \qquad \text{Equation 2}$$

The subscripts i and y in equation *(1)* stand for a country and years accordingly, y_{it} is the amount of CO2 emissions per capita in metric tons, x1 – share of Wind and Solar energy use for electricity generation in %, x2 – GDP international logged naturally, x3 – share of Hydroelectric sources for electricity generation in % of the total and ε_{it} is the residual. The deviations of predicted results from the real ones are shown in the residuals column. The list of residuals is provided in the Appendix. When we add up all the residuals, the sum we get is equal to 0. According to our equation, we have the following results:

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Table1 Panel Regression Output

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
CO2..Y..emissions. per.capita	380	0	380	1.702	20.472	7.443	4.064
Share.of.X1..wind.and. solar.in .electricity.producti on....	380	0	380	0.000	24.558	5.501	6.372
Ln.GDP..X2..international.2017	380	0	380	8.147	11.028	10.389	0.534
Electricity.production.X3..from .hydroelectric.sou rces....of.total.	380	0	380	0.050	87.244	19.229	20.770

Results for variable CO2..Y..emissions.per.capita:
Goodness of fit statistics:

rsq 0.468 adjrsq 0.436

Joint test of significance (F or Chi-square test):

statistic.F	parameter.df1	parameter.df 2	p.value.F
104.811	3	357	<0,0001

Coefficients:

	Estimate	Std. Error	t-value	Pr(>|t|)
Share.of.X1..wind.and.solar.in.electricity.producti on....	-0.133	0.008	-17.119	<0,0001
Ln.GDP..X2..international.2017	2.635	0.273	9.655	<0,0001
Electricity.production.X3..from.hydroelectric.sou rces....of.total.	-0.028	0.011	-2.587	0.010

RESULTS AND DISCUSSION (Натижалар ва муҳокама/ Результаты и обсуждение)

The measure of economic growth - GDP - reflects the increase in the value of manufactured goods and services in a given country in a specific period (value of goods and services produced minus the value of goods and services used in production) (Campo and Sarmiento, 2013). It is worth remembering that the concept of "economic growth" is not the same as "economic development", which additionally includes qualitative changes accompanying economic growth, improving the competitiveness of a given economy.

Regardless of whether energy consumption leads to economic growth or the opposite, most studies have considered the GDP as a representative for economic growth and a predictor for CO2 emissions. Estimating environmental drawback brought by economic progress has been in the focus of scholarly interest since Paris agreement has been adopted, followed by SDG. Global warming, which is mainly the result of excessive CO2 has become a global threat to humanity.

The rise of an average annual temperature has led to floods and droughts [15], resulting in deforestation, diminishing the areas for farming and many other negative impacts on agriculture. The study of the energy and GDP impact on CO2 emissions has been growing since then.

CONCLUSION (Хулоса/Заключение)

Reducing the negative impacts of human economic activities is a global priority. Clean and safe energy is seen as a necessary mitigation approach to reducing the negative externalities of economic growth while retaining significant economic growth. Governments need to raise public awareness of environmental protection and reduction of CO2 emissions by working with various platforms, such as television, the internet, and radio. This will help more families and individuals understand the importance of pollution control. Governments need to develop and enforce emission reduction policies and energy conservation schemes, as well as attach corresponding measures to encourage production units to adopt green technologies and severely punish those who don't.

According to https://data.worldbank.org/indicator an average person in 2018 emitted 4.5 mt tons of CO2 which is 0.6mt tons more compared to 1990's average. Our findings suggest that 1% increase in solar and wind energy use for electricity, mitigates CO2 emissions by 0.133 mt tons per capita, that is almost 3% of 4.5 mt tons.

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