“Potential of investments into renewable energy sources”

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ARTICLE INFO	Dominika Čeryová, Tatiana Bullová, Izabela Adamičková, Natália Turčeková and Peter Bielik (2020). Potential of investments into renewable energy sources. *Problems and Perspectives in Management*, *18*(2), 57-63. doi:10.21511/ppm.18(2).2020.06
DOI	http://dx.doi.org/10.21511/ppm.18(2).2020.06
RELEASED ON	Friday, 24 April 2020
RECEIVED ON	Sunday, 16 February 2020
ACCEPTED ON	Thursday, 09 April 2020

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JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
26	1	3

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BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

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POTENTIAL OF INVESTMENTS INTO RENEWABLE ENERGY SOURCES

Abstract

Greening the economy requires green innovations, and innovations require investments. Most countries of the world are still relying on conventional (fossil-based) sources of energy. The transition toward green or renewable energy sources is an effective and innovative way to meet ever-increasing demand as a result of the rising population. Another reason for innovations in the field of green energy is the need to mitigate climate change and avoid pollution, especially in developing countries. The monitored investments into renewable energy sources are usually public. Therefore, this paper aims to determine whether the selected countries of the world produced renewable energy efficiently, considering the investments made by public financial institutions and installed electricity capacity for renewable energy sources, for the period 2013–2017 (for a deeper analysis, the year 2017 was chosen). For this purpose, the Stochastic Frontier Analysis model in the logarithmic form of the Cobb-Douglas production function is used, which helps to judge the competitiveness of countries based on effectively transforming the inputs into outputs. Results suggest that the effect of the first variable "installed electricity capacity" on electricity generation was highly statistically significant, and the impact of the second variable "public investments" was characterized as statistically insignificant. The monitored countries were divided into 10 groups according to the different range of estimated output-oriented technical efficiency from 0.00 to 1.00. Most countries should increase the renewable electricity generation approximately by 40-49%, given the level of inputs (16 countries of 6th group with estimated output-oriented technical efficiency 0.51-0.60) for the year 2017.

Keywords electricity capacity, electricity generation, inputs, outputs, efficiency, public investments

JEL Classification C67, Q20, Q42

Received on: 16th of February, 2020
Accepted on: 9th of April, 2020
Published on: 24th of April, 2020

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Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

Renewable energy is derived from renewable sources (water, wind, solar, geothermal, and biomass energy). It is often referred to it as clean energy because it comes from natural processes that are constantly replenishing. Investing in these innovative solutions can fundamentally change the way energy is produced, stored, and used, thereby gradually ensure moving from fossil fuels to renewable energy. Investments from public financial institutions in 2017 amounted to USD 29,101 million worldwide, 6,190,948 GWh of renewable energy was produced, and devices for the use of renewable energy sources with an output of 2,181,577 MW were installed (International Renewable Energy Agency, 2019). The main objective of the paper is to find out whether the countries of the world under study produce energy from renewable energy sources efficiently with respect to investments provided by public financial institutions and installed electricity capacity for renewable energy sources. To achieve the main objective, the Stochastic Frontier Analysis (SFA) model is used to monitor not only the direct dependence between inputs and outputs but also the efficiency of input to output transformation → output-oriented technical efficiency, which also helps in assessing the competitiveness of the countries.

1. LITERATURE REVIEW

1.1. Renewable energy sources

Energy use and its influence on the environment is the one among the foremost important challenges facing humanity in the 21st century (Connolly, Mathiesen, & Leahyal, 2011; Pusnik, Sucic, Urbancic, & Merse, 2012, p. 703). The sources of energy are divided into three groups: fossil fuels, renewable sources, and nuclear sources (Demirbas & Dincer, 2008, p. 1233). To address climate change and limited fossil fuel resources, renewable energy technologies are increasingly being installed into power grids. Renewable energy sources will likely become the prevailing source of power soon (Dooner & Wang, 2019, p. 1) because the utilization of renewable energy sources for countries of the world shows an increasing trend in recent years (Aydin Yenioglu & Altes, 2019, p. 863). Renewable technologies are thought of as clean energy sources, so their optimal usage reduces environmental impacts, produces a minimum of secondary waste, and is sustainable based on current and future economic and social needs (Panwar, Kaushik, & Kothari, 2011, p. 1513). Carbon mitigation is the main goal of the power – generation regulation; therefore, according to Martinez-Fernandez, deLlano-Paz, Calvo-Silvosa, and Soares (2019, p. 1), renewable energy sources are important to design a future low-carbon mix.

1.2. Renewable energy generation, public investments, and installed electricity capacity for renewable energy sources

Niamir and Filatova (2017), Niamir, Kiesewetter, Wagner, Schopp, Filatova, Voinov, and Bressers (2019) state that many energy-related actions pursue the influence of electricity consumption. For example, an individual can invest in renewable energy technologies (p. 4). The authors agree with these scientists and add that investment can be made not only by the individual but also the whole country. The energy sector increasingly supports renewable energy sources. Nowadays, energy sector and energy policies are the main factors that determine the position of countries (Incekara & Ogulata, 2017; Ozbilen et al., 2019, p. 1016). Behuria (2020) mentions that "renewable energy investments are expanding across the world at an astonishing rate, e.g., the United States and Europe obtained early advantages in renewable energy technologies, and East Asian late industrializers have now extended substantial support to domestic renewable energy manufacturing firms alongside encouraging the increased deployment of renewable energy projects. On the other hand, developing countries have lagged in their support to manufacturing segments of the renewable energy sector" (p. 1). Moreover, Quitzow, Thielges, Goldthau, Helgenberger, and Mbungu (2019) add that investments in clean energy remain largely focused on a small number of frontrunner countries and overwhelmingly target grid-connected electricity generation. Worryingly, a significant share of international public sector investment (notably by export credit agencies) is still allocated to coal and other fossil-based technologies (p. 1). "The escalating demand for energy, most of which is still generated by mentioned coal combustion as of today, only exacerbates the situation of carbon dioxide emission during the power generation. Very few carbon capturing or utilization technologies are mature enough to reduce the CO2 emission on an economically competitive scale. Electricity generation from renewable energy sources typically entails high capital investments, thereby keeping them from being competitive in the energy marketplace" (Chuang, Lien, Den, Iskandar, & Liao, 2018, p. 422). A wide variety of economic advantages are generated by using energy from renewables. One of them is the fact that several renewable energy applications could be cost-effective (investors in new technologies will save more money from decreased use of fossil fuels). Investing in renewable energy can help expand economics. Instead of main sources spread across a range of technologies, depending on what resources are available in any particular location – wind, sun, water, geothermal springs, or biomass (Akella, Saini, & Sharma, 2009, p. 391). "Public policy and finance have an important role in creating enabling conditions for renewable energy investments. Public finance institutions provide public capital to support public and private sector projects, as well as policies and programs that serve the public good with economic, environmental, or social benefits. Several such institutions have been established and resourced to sup-

http://dx.doi.org/10.21511/ppm.18(2).2020.06

port renewable energy investment. The main types of public finance institutions are international financial institutions, e.g., the European Investment Bank, development finance institutions, e.g., the German Development Bank, local financial institutions, export credit agencies, climate finance institutions, e.g., Green Climate Fund" (Wuester, Lee, & Lumijarvi, 2016, pp. 27-29).

1.3. Efficiency

According to Karlaftis and Tsamboulas (2012), the term efficiency refers to the comparison between the real or observed values of output/outputs and input/inputs with the optimal values of input/inputs and output/outputs (p. 393). According to Shumais (2020), there exist two ways of measuring the efficiency, specifically, the output efficiency that measures how far an inefficient unit (e.g., country) can increase its output to reach the frontier with the level of inputs in incorporates, and the input efficiency that determines how far a unit can decrease its input usage for a given level of output it produces (p. 113). Bezat-Jarzębowska and Rembisz (2013) state that the efficiency of input factor use (not the increase of it) is the main factor of producer's competitiveness that is expressed by the ability for a long-term and effective growth and performance (p. 359). Economic efficiency combines technical efficiency (mentioned in this paper) and allocative efficiency, with technical efficiency referring to the increase of output given a fixed level of input, and allocative efficiency allowing adjustment of input to meet consumer preferences (Liu, 2019, p. 114). The area of efficiency and productivity analysis using frontier estimation methodologies has been developing very rapidly in the last four decades – nonparametric approach Data Envelopment Analysis (DEA) and parametric approach Stochastic Frontier Analysis (SFA) (Daraio, Kerstens, Nepomuceno, & Sickles, 2020, p. 709). Stochastic Frontier Analysis in the Cobb-Douglas model is the most generally used model with a combination of multiple inputs and describes current technology in the industry. This model is well-known, as it offers consistency, versatility, and relative simplicity of estimating efficiency (Moreira Lopez, Bravo-Ureta, Arzubi, & Schilder, 2006; Azizul, Anton Abdulbasah, & Kanis, 2009; Y. Yuan, Y. M. Yuan, Dai, Zhang, Gong, & Y. Q. Yuan, 2019, p. 310). This parametric method evaluates the production function showing maximum output that is achievable with given technology from an array of inputs with due allowance for statistical noise (von Furstenberg, 2008, p. 548).

2. AIM, DATA, AND METHODS

The main objective of the paper is to determine whether the countries of the world under study produce renewable energy efficiently, considering the investments made by public financial institutions and installed electricity capacity for renewable energy sources.

The research considers countries of the world, which were financed by public financial institutions for the support of renewable energy sources annually, during the monitored period 2013–2017. Countries are examined from the perspective of the renewable energy situation in total for hydropower, wind, solar, biomass, and geothermal energy.

Table 1. Objects of research

Source: Own processing (International Renewable Energy Agency, 2019).

Region	Country
Africa	Algeria, Burkina Faso, Burundi, Cabo Verde, Cameroon, Congo DR, Egypt, Ethiopia, Gabon, Ghana, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Nigeria, Sao Tome and Principe, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia
Asia	Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Kazakhstan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Tajikistan, Thailand, Turkmenistan, Vietnam
Central America and the Caribbean	Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama
North America	Mexico
Eurasia	Armenia, Georgia, Turkey
Europe	Austria, Belarus, Bosnia and Herzegovina, France, Kosovo, Republic of Moldova, Norway, Serbia, Sweden, UK, Ukraine
Middle East	Jordan, Lebanon, Palestine
South America	Argentina, Bolivia, Brazil, Colombia, Ecuador, Chile, Peru, Uruguay
Oceania	Fiji, Marshall Islands, Papua New Guinea, Samoa, Solomon Islands

The Statistical Department of the International Renewable Energy Agency provided the data used for the research part of the article to achieve the main objective.

SFA model is applied when examining the efficiency of converting inputs in the field of renewable energy sources (investments from public financial institutions, installed electricity capacity for renewable energy sources) to output (energy generation from renewable energy sources). There is used the general SFA model in the logarithmic form of the Cobb-Douglas production function, which is based on panel data corresponding to the period 2013–2017:

$$\ln y_{it} = \beta_0 + \sum_{i=1}^{n} \beta_n \ln x_{nit} + v_{it} - u_{it}, \qquad (1)$$

where i – number of observed units, n – number of inputs, t – time period of measurements, x_i – input matrix, dimensions of which depend on the number of inputs and measurements, β – estimated parameters.

The number of observations that enters the model is 445 in 89 groups (monitored countries of the world) over 5 years (2013–2017). All calculations are performed in Stata 15.

3. RESULTS

SFA model is statistically significant (Prob > chi2 = 0.0000).

The production function is in the following form:

$$\ln \text{GENERATION} = 9.859 + \\ +0.921 \ln \text{CAPACITY} + \\ +0.004 \ln \text{INVESTMENT} + (v_i - u_i).$$

The values of the production function coefficients can be interpreted as the percentage change in output caused by the percentage increase in input. In the case of the above production function, should the amount of installed electricity capacity for renewable energy sources increase by 1%, an increase in electricity generation from renewable energy sources by 0.921% is expected. The effect of the interpreted variable is highly statistically significant (Table 2 – p > |z| = 0.000 (0.05 > 0.000) statistically significant). In case the countries under study would invest 1% of the funds provided by public financial institutions, there would be an increase of only 0.0004% in electricity generation from renewable energy sources. The impact of investments can be characterized as statistically insignificant (Table 2 – p > |z| = 0.398 (0.05 < 0.398) statistically insignificant). Both coefficients are inelastic, as their value is less than 1. The gamma value (gamma = 0.9333272) indicates that 93% of the variability of output across countries is attributed to differences in technical efficiency.

From the viewpoint of monitoring the situation in selected countries of the world, it is not only important to interpret the relationship between selected inputs and outputs but also estimate whether the conversion of inputs to output in the renewable energy sector is effective. For this reason, output-oriented technical efficiency was estimated through the SFA model. For a deeper analysis, the year 2017 was chosen. The monitored countries were divided into 10 groups. Each group represents a different range of estimated output-oriented technical efficiency from 0.00 to 1.00 (Table 3). One considers the model country to be the one whose estimated technical efficiency is equal to 1.00, i.e., a country would not have to change its electricity generation from renewable energy sources in terms of inputs to be considered efficient.

In the first group (with an estimated output-oriented technical efficiency of 0.00-0.10), there is no country included out of the monitored countries of the world that invested money from public financial institutions in renewable energy sources. It can, therefore, be concluded that none of the countries uses its inputs inadequately.

Table 2. SFA model output

Source: Own research (Stata 15).

GENERATION	Coef.	Std. err.	z	*p* > |*z*|	[95% conf. interval]	
CAPACITY	.9212458	.0226835	40.61	0.000	.8767869	.9657047
INVESTMENT	.0037461	.0044318	−0.85	0.398	−.0124323	.0049401

http://dx.doi.org/10.21511/ppm.18(2).2020.06

Table 3. Intervals of estimated output-oriented technical efficiency (the year 2017)

Source: Own research.

1st group	0.00-0.10	0 countries
2nd group	0.11-0.20	4 countries
3rd group	0.21-0.30	11 countries
4th group	0.31-0.40	12 countries
5th group	0.41-0.50	6 countries
6th group	0.51-0.60	16 countries
7th group	0.61-0.70	13 countries
8th group	0.71-0.80	13 countries
9th group	0.81-0.90	8 countries
10th group	0.91-1.00	6 countries

The biggest group is 6th group with an estimated output-oriented technical efficiency of 0.51-0.60. 16 out of 89 countries in the world are included in this group. Countries within this group for unchanged inputs should increase electricity generation from renewable energy sources as follows: Turkey and Sri Lanka by 47% (TE = 0.53), Guatemala, Mauritius and Georgia by 46% (TE = 0.54) , Honduras by 45% (TE = 0.55), Bosnia and Herzegovina, United Kingdom by 44% (TE = 0.56), India by 43% (TE = 0.57), Austria, Nigeria, Mexico, and Panama by 42% (TE = 0.58), Bolivia and Tanzania by 42% (TE = 0.59) and Burundi by 40% (TE = 0.60). In case countries increase electricity generation from renewable energy sources by the above percentages, one would consider them to be efficient in terms of converting inputs to output in the renewable energy sector.

In the last (10th) group, some countries are the most efficient out of 89 monitored countries in terms of output-oriented technical efficiency. These include Mozambique (Africa), Peru (South America), Cameroon (Africa), Zambia (Africa), Brazil (South America), and Norway (Europe). Their output-oriented technical efficiencies range from 0.91 to 1.00. For unchanged inputs, an increase of 9% in electricity generation from renewable energy sources is needed in Norway, 8% in Brazil and Zambia, 7% in Cameroon and Peru, and only 3% in Mozambique[1]. Following this percentage increase, countries would achieve an output-oriented technical efficiency value of 1.00 and would be considered model countries, which do not need to change electricity generation from renewable energy sources in terms of inputs and still be efficient.

The figure shows the output-oriented technical efficiency of the countries under study in 2017 compared to the technical efficiency that belongs to the model countries, i.e., their output-oriented technical efficiency = 1.00.

Source: Own research.

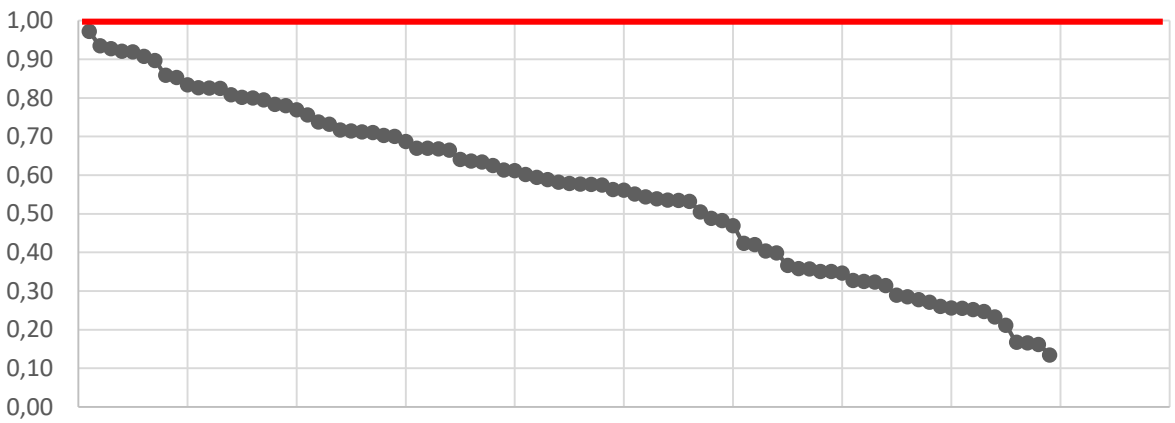

Figure 1. Output-oriented estimated technical efficiency (2017)

1 Given the data for the whole country.

CONCLUSION

Energy plays an important role in economic and social development. Globally, countries heavily depend on fossil fuels like coal, oil, and natural gas to meet their energy demands. Renewable energy and biofuels are now on the top of innovations list with the greatest impact on society and business. The main objective of the paper was to determine the effect of investments made by public financial institutions and installed electricity capacity for renewable energy sources in terms of the efficiency of renewable energy generation. Renewable energy is considered as the alternative to current fossil-based energy. Global investments poured into renewable energy usually flow from public resources. The efficiency of production depends on many factors, among others, these investment flows and the installed electricity capacity for renewable energy sources. The SFA model was employed to estimate the efficiency of converting inputs in the field of renewable energy sources (investments from public financial institutions, installed electricity capacity for renewable energy sources) to output (energy generation from renewable energy sources). The monitored countries were divided into 10 groups, and each group represented a different range of estimated output-oriented technical efficiency. The biggest group was 6th group with an estimated output-oriented technical efficiency of 0.51-0.60. In this group, 16 out of 89 countries in the world were identified. Therefore, given the level of inputs, most countries should increase the production of renewable energy by approximately 40-49%. However, it is important to note that the results might be improved if one could employ the data on private investments as well. Private investments are mentioned, e.g., in Ragosa and Warren's (2019) research. They tested the effects that a variety of factors had on foreign investment in renewable power generation in developing countries.

AUTHOR CONTRIBUTIONS

Conceptualization: Dominika Čeryová, Tatiana Bullová, Izabela Adamičková, Natália Turčeková, Peter Bielik.
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Investigation: Dominika Čeryová.
Methodology: Dominika Čeryová.
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Visualization: Dominika Čeryová.
Writing – original draft: Dominika Čeryová.
Writing – review & editing: Dominika Čeryová, Tatiana Bullová.

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