SUSTAINABLE DEVELOPMENT FACETS: ROLE OF RENEWABLE ENERGY PRODUCTION, CONSUMPTION AND RESEARCH AND DEVELOPMENT EXPENDITURE

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Abstract. With the increasing importance of innovative technologies, the significance of aspects such as renewable energy production and consumption and R&D expenditures cannot be ignored. The economy of the country as well as of other industrial sectors may be enhanced by the use these aspects in one way or the other. In this study, the author is supposed to find out the impact of the above mentioned three aspects on sustainable development in a country. The collected data for this purpose is based on Asian countries and covers the time period of 28 years. The tests that have been used by the author in order to scrutinize the collected data include LLC unit root test, different diagnostic checks and most importantly PCSE and GMM tests. By using these tests, after the exploration of order of integration, the relationships between different variables was investigated. The results of these tests indicate that the impact of renewable energy production and consumption as well as R&D expenditure is significant in context of sustainable development. Apart from these variables, the impact of one control variable, economic growth has been found to be significant. This study has many theoretical, practical and policy making implications. Moreover, several limitations have also been discussed by the author.

Keywords: sustainable development; renewable energy production; consumption; research and development expenditure; Asia

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JEL classifications: O1, O32, Q20

1. Introduction

Since 2000, progress over responsible production and consumption, ‘doing better and more with less’ has resulted into regressing most of the objectives. Particularly, regions should work for sustainable usage of natural resources like management of chemical wastes, land and water. Northeast Asia and East Asia that involves Mongolia, Japan, South Korea, North Korea, Macau, Hong Kong and China is the leading region in making efforts towards zero hunger and no poverty. Central and North Asia has worked a lot for six of Sustainable Development Goals: strong institutions and justice, peace and life below water, climate action, responsible production and consumption, decreased inequalities, sanitation and clean water (Abbas et al., 2018). In accordance with Ahmed, Al-Amin, Ambrose, and Saidur (2016) Southeast Asia that involves Thailand, Vietnam, Timor-Leste, Laos, Malaysia, Laos, Indonesia and Brunei has made major improvements in giving quality education, ensuring clean energy and access to affordable energy. Bayulgen and Ladewig (2017) listed six biggest producers of renewable energy in Asia dependent on the installed capacity of renewable energy in year 2018. China is not just the largest producer of renewable energy within Asia, but in entire world, with the capacity of generation as twice of US. In accordance with Bhuiyan et al. (2018), India is the second largest producer of renewable energy within Asia. The country mainly produces hydroelectric power that have 50GW installed capacity. For Japan, Hydropower is the major source of renewable energy, because of various projects of hydroelectric projects.

Figure 1. Consumption of Oil by Asian Countries

Vietnam develops over 90 percent; Pakistan makes 76 percent and South Korea makes 50 percent of the renewable energy through hydropower plants. With most of the countries within Asia witnessing development in economy, the requirement for energy is also increasing. Currently, the continent has around 30 percent requirement of global energy. However, there is no doubt that economic development of India and China had mainly contributed to the increment in demand of energy. However, in accordance with Cai and Aoyama (2018), in developed countries of Asia, past oil crises experience has outcome into ethos of efficiency in consumption of energy and decreasing the demand of oil. Consumption of oil by Asian countries is given in figure 1. Expenditures for development and research are capital and current expenditures on creative work that is done for enhance knowledge, involving experimental development, applied research, society, culture, knowledge usage and humanity (Ghosh, 2016). Map provided in figure 2 shows that how expenditure of Research and development differs by country within Asia.

Figure 2. Research and Development Expenditure in Asia

The sustainability development of Asian countries is declining. The reason is that energy production, energy consumption and expenditure of research and development are getting affected badly (Haseeb, Kot, Hussain, & Jermisittiparsert, 2019; Jermisittiparsert & Chankoson, 2019). This problem is not only suffered by Asian countries, but other European and Asian countries also suffer from this problem. In case if this problem will not be addressed, the country can lose a lot of revenue and it can also result into a negative effect over the sustainable development of country (Gu, Renwick, & Xue, 2018). In past, sustainable development has been studied in detail. However, there is no such research that involves overall analysis of impact of renewable energy production, energy consumption and research and development expenditure over sustainable development of Asian countries (Hancock, Ralph, & Ali, 2018). Moreover, in none of the researches, latest panel data analytics methods have been used for the analysis of sustainable development of Asian countries (Gupta, De, Gautam, Dhar, & Pandey, 2018). Therefore, this research will involve the overall analysis of sustainable development of Asian countries. This study has following objectives:

1. To analyze the impact of renewable energy production on sustainable development of Asian countries
2. To check the role of energy consumption on sustainable development of Asian countries
3. to determine the impact of research and development expenditure on sustainable development of Asian countries

The other related researches that have been done on sustainable development have not provided detailed analysis of sustainable development of Asian countries. Moreover, these researches have not tested the impact of these variables over the economic growth of Asian countries. Therefore, the findings of this research will help Asian countries to increase sustainable development.

The division of dissertation has been done into Introduction, Literature Review, Methodology, Analysis, Findings and Conclusion.

2. Literature Review

2.1 Impact of Role of Renewable energy Production on Sustainable Development

Renewable energy is described as energy acquired through naturally replenishing resources that are identified as inexhaustible. Basic kinds of renewable sources of energy are geothermal energy, wind energy, hydropower, solar energy and biomass. Sustainability involves three pillars like society, ecology and economy (He, Zhao, Zhu, Darko, & Gou, 2018). The term sustainable development as given by Khanna et al. (2019) is defined as development that fulfills the requirements of present without making compromise on the ability of future generations to fulfill the requirements. For sustainable development. Ensuring supply of sustainable energy is the most significant prerequisites of sustainable growth. Sustainable economic development is the development of economy linked with improving individuals' living standards through giving secured and lasting livelihood, decreasing degradation of environment and depletion of resources. It is identified as a holistic approach of linking development of economy with the development of environment and society (Kirchherr & Urban, 2018). For different countries that are at the phase of take-off stage of investments of renewable energy, can adopt initiatives of market development, tax incentives and can create public to private partnership in order to finance various renewable projects at lower rate of interest. Asian countries should enhance the productivity of renewable energy in order to give boost to sustainable development (Liu, 2019). The real set-up within developing and emerging economies of Asia is surrounded through the barrier of politics, economy and society. For supporting the sector of renewable energy, it is significant to decrease the investment risk and to alter the complicated processes of acquiring loan. Private sectors and government should make partnership public to private in order to remove the barriers and for decreasing the risks that are seen while making investment in renewable energy (Moore, 2017).

H1: There is a significant impact of renewable energy production on sustainable development of Asian countries.

2.2 Impact of Role of Renewable energy Consumption on Sustainable Development

Renewable energy consumption holds important influences over sustainable development and CO₂ emissions across Asian countries. The report of International Renewable Energy's Agency (IRENA) over the capacity of international renewable energy identifies that the capacity of renewable energy within Asia approached at 918 GW in year 2017. India and China made major contribution in the given section. China is the major contributor in the worldwide development of renewable power that makes more capacity. In year 2017, solar capacity of China got 36 times more as compared to what it was five years before (Oh, Hasanuzzaman, Selvaraj, Teo, & Chua, 2018). In year 2016, 130 GW electricity was produced through solar power, which was more than what the government targeted for year 2020. Currently, the projects of renewable energy are becoming important in energy mixes of mostly countries (Orhan, Kahraman, & Babu, 2017). In accordance with Rauf et al. (2018), the consumption of renewable energy can give more benefit to the economic and sustainable development and can decrease emissions of CO₂ in long race. For ensuring sustainable economic growth, developing and emerging countries of Asia should target on making investment in the sector of consumption of renewable energy. Successful integration of projects of renewable energy are seen dependent over adoption of appropriate package of policy rather than selecting stand-alone procedures. Currently, the practiced policies of renewable energy are renewable standards that act as cost effective choice to decrease initial technology cost, lower interest loans, green certificates as the assets that can be traded for generating electricity through renewable resources. Through the research of Shakeel, Takala, and Zhu (2017), it has been identified that such countries where there is positive influence of consumption of renewable energy, the investment focus has been shifted to the sector of consumption of renewable energy. Such countries can take various policy initiatives like feed-in tariffs, standards of renewable portfolio, development of fossil fuel and green certificates for long-term development of economy. Countries such as South Africa, India, China AND Egypt have taken some of the advanced measurement in the policy packages of renewable energy consumption (Shouman, 2017; Radwan, Sakr, 2017; Rezk, Radwan, Salem, Sakr, Tvaronavičienė, 2019).

The consumption of some of the renewable energy sources can outcome into some issues. For instance, consumption of biofuels can result into deforestation, which has some of the consequences such as food crops' displacement, loss of biodiversity and social dislocation. Addressing the given issues, like increasing biofuels' efficiency to ensure sustainable development can be the other research field (Spangenberg, 2019).

***H2:** There is a significant impact of renewable energy consumption on sustainable development of Asian countries.*

2.3 Impact of role of Research and Development Expenditure on Sustainable development

The good news is that more of the countries are now making more investment in research and development (R&D). On the other hand, the bad news is that richer countries are making more of the investment and poor countries that actually need it are not making it (Thapar, Sharma, & Verma, 2017). International spending over Research and Development has approached around \$1.7 trillion. It basically involves 10 of the countries that account for 80% of spending in accordance with UNESCO (UN Educational, Scientific and Cultural Organisation). Asian countries have pledged to make an increment in R&D expenditure of public sector and private sector (Wakeel, Chen, Hayat, Alsaedi, & Ahmad, 2016). In previous month, UNESCO released a new tool of data depicting the international leaders and other emerging players within Research and Development. While releasing the data tool, the director of UNESCO Institute for Statistics stated that innovation is the major key to acquire every goal of Sustainable Development as given by B. Wang, Wang, Wei, and Li (2018). Therefore, it is important to track investment in R&D in the thinking, technology and knowledge that drives more innovation within countries. It is of no surprise

that some of the Asian giant countries in terms of economic and population clout, top the list of nations of UNESCO that made investment in R&D (Khurshid, Rashid, & Zahid, 2018). US leads 15 of the countries in R&D spending at US \$457 billion in PPP (purchasing power parity) with the business region mainly contributing to 70.6 percent. Two of the economic giants of Asia, Japan and China follow behind in 2nd and 3rd place. Asia has four of the countries that are in top ten spenders of UNESCO R&D, with more of the investments of R&D coming through the respective sectors of business except for India that is present at 7th place (Q. Wang, Zeng, & Wu, 2016). There were around 1083 researchers for around one million individuals in year 2013. The data acquired from UIS identify that this number is reducing for the countries that have been middle-income between years 1996 to 2013 as provided by Zou, Zhao, Zhang, and Xiong (2016). It is downward trend that has some of the global implications for the purpose of sustainable development. UN should solve the given problem as it develops the goals of Sustainable development. Therefore the government calls SDG for promoting innovation and sustainable industrialization through ramping up more spending over R&D and enhancing the total number of researchers (Walters, 2016).

H3: There is a positive impact of research and development expenditure on sustainable development of Asian countries.

3. Methodology

3.1 Data

As discussed in earlier sections of the study, it has been evident that this study revolves around the production as well as consumption of renewable energy, research and development expenditures and sustainable growth, the data has been collected by the author in context of these variables from Asian countries. The collected data covers the time period of 28 years and has been collected from the World Bank Indicators by World Bank database. The author also used the Global Economy database in this regard.

3.2 Model Specification

The variables that are used in this particular study are classified into dependent, independent and control variables. The dependent variable of this study is sustainable development. The independent variables of this study include renewable energy production and consumption, and R&D expenditures. Apart from these variables, two control variables were also included by the author in this study. These variables include economic growth and per capita income. The measurement units of all these variables have been discussed here. Sustainable development SD has been measured in terms of GDP growth in this study. Renewable energy production REP has been measured in terms of billion kilowatt hours. In the same way, renewable energy consumption REC has also been measured in terms of billion kilowatt hours. R&D expenditure RDE has been measured through million US dollars. The first control variable, economic growth EG has been measured in terms of GDP growth in a country while the second control variable, per capote income has been measured in terms of US dollars. Using all these units and notations, the author has generated the following regression equation to be used in the research procedure:

$$SD_{it} = \alpha + \beta_1 REP_{it} + \beta_2 REC_{it} + \beta_3 RDE_{it} + \beta_4 EG_{it} + \beta_5 PCI_{it} + \varepsilon_{it}$$

In this equation, different variables are represented by using their short forms such as; sustainable development has been shown by SD, renewable energy production has been represented by REP, renewable energy consumption has been represented by REC, R&D expenditure has been donated by RDE, economic growth has been presented by EG, per capita income has been shown by PCI and ε_{it} represents the error.

3.3 Estimation Procedures

3.3.1 Unit Root Test

The first test that is used in the research process is panel unit root test that is applied on the collected panel data. The basic purpose to use this test is to identify the order of integration and the stationary and non-stationary properties of the variables and data. An important point to be discussed here is that the old and conventional tests did not provide accurate and authentic results (Pesaran, 2004). This was due to the reason that they caused some size and power related problems. To resolve these problems and issues, new unit root tests were developed from augmented Dickey Fuller test ADF. These tests include Levin Lin Chu LLC and Im Pesaran Shin IPS tests. LLC unit root test provides same autoregressive process while IPS provides heterogeneous autoregressive process. Both these tests involve two series i.e. level series and first difference series, the values of which are used to determine whether the null and alternate hypotheses are accepted or rejected. The null and alternate hypothesis must be clearly understood before evaluating and interpreting the results of these tests. The null hypothesis involves that unit root is present in the data and data is stationary. On the contrary, the alternate hypothesis involves that unit root is absent while the data is stationary. Based on these hypotheses, these tests are conducted and evaluated. The author has used LLC unit root test in accordance with the following equation:

$$\Delta y_{i,t} = a_i + \rho y_{i,t} - 1 + \sum_{j=1}^{pi} a_j \Delta y_{i,t-j} + \varepsilon_{i,t}$$

Here $\Delta y_{i,t}$ is the difference that $\Delta y_{i,t}$ shows for i^{th} country for the specific time period of t .

3.3.2 PCSE and GMM Test

The following general equation for the estimation of the variables can be used:

$$QE_{it} = \alpha + \sum_{j=1}^7 B_j X_{it} + \sum_{j=1}^4 \delta_j CEF_{dumj} + \sum_{j=1}^{30} \theta_j Y_j + \varepsilon_{it}$$

In this equation, α is the constant value, I represents the country, t represents the time or year, X_{it} shows the explanatory variable, B_j is its coefficient, CEF_{dumj} shows the country fixed effect dummy and δ_j is its coefficient.

As shown in the equation given above, it is very evident that fixed effect dummy has been used in this research. There are many benefits of fixed effect dummy, the most important of which is that time series and aggregate trends reduce the cross-country regression among the variables of the study. In addition, any structural break present in the gathered data can also be probed by using this fixed effect dummy in the equation. After unit root tests, the data collected is passed through some basic diagnostic tests such as heteroscedasticity test, cross sectional dependence test, autocorrelation test and multicollinearity test for various purposes such as to find the heteroscedasticity of the variables, autocorrelated relationships, and multicollinearity relationships and cross sectional dependence of the selected variables. The use of these tests is very beneficial before the application of main PCSE and GMM tests because of the fact that accurate and authentic results can be effectively obtained and without these tests the results are really ambiguous and unclear that creates difficulty for the researcher as well. The results of these tests also indicate the fact that what types of tests or approaches may be used in order to measure the relationships between the variables. The results of these tests mentioned above have been presented in the table 1 of the study. The results from these tests show that significant heteroscedasticity and cross-sectional dependence is present among the collected data. These results also indicate the fact that no autocorrelation and multicollinearity has been found in the selected sample of the data.

Table 1. Diagnostic checks

Heteroskedasticity	Autocorrelation	Cross-section dependence	Multicollinearity
Modified wald Breusch-Pagan/Cook-Weisberg	Wooldridge	Pesaran	VIF
χ^2 -value: 8.11** χ^2 -value: 4.56**	F-statistic: 9.78*	Test statistic: 2.641**	Mean VIF: 1.23

After the application of basic diagnostic tests and the interpretation of their results, the author has further applied correlation test on the data and has obtained a correlation matrix in the table 2. The correlation matrix basically indicates that whether correlation bias is present among the variables or not. It also shows the relationship between the variables. The results presented in table 2 show that there is no correlation bias among the variables under study in this particular research.

Table 2. Correlation Metrix

Variables	REP	REC	RDE	EG	PCI	SD
REP	1					
REC	.432	1				
RDE	.104	.294	1			
EG	.395	.238	.284	1		
PCI	.139	.385	.573	.384	1	
SD	.593	.538	.528	.287	.283	1

When the issues such as heteroscedasticity and cross-sectional dependence have been found, the author has applied PCSE and GMM tests and approaches in order to resolve these issues. These tests are important because without the application of these tests, the results of the test would not be authentic and accurate. This shows that how much important is the use of PCSE and GMM estimation techniques are in this case (Blundell & Bond, 1998). During the application of these techniques, two types of fixed effects have been used by the author. These include country fixed effect and time fixed effect. There are several purposes for which these fixed effects are used. The PCSE test is assumed to have by default presence of fluctuations in their results and these are because of the presence of heteroscedasticity and correlations between the variables. The other and most important test used for the same purpose is GMM test in which the endogeneity problems and issues can be resolved by using lagged values of estimators. In addition, studies have shown that two types of GMM tests are generally found. These include first differenced GMM and system GMM tests. System GMM test are more effective as the first differenced GMM tests show inaccurate results in case of small sample size of the gathered data (Arellano & Bover, 1995). On the contrary, the system GMM test proves very creditable results and also connects two types of regressions. In other words, level regression and first difference regression can be joined by the use of system GMM test. GGM estimation technique may be used in accordance with the following equation:

$$\vartheta_{it} = \alpha_i + \gamma \vartheta_{it-1} + \sum_{p=1}^p \beta_p Z_{it}^p + \sum_{q=1}^q \beta_q Z_{it}^q + \sum_{r=1}^r \beta_r Z_{it}^r + \epsilon_{it}$$

4. Empirical Results

4.1 Results of Unit Root Test

As the author has employed unit root test of Levin Lin Chu in this study, the results are shown in detail in the table 3 of the study. It must be noted that level series and first difference series values have been shown in the table with different significance levels of rejection of null hypothesis. First of all, the level series of the table shows that all of the variables in this series have accepted the null hypothesis except one variable i.e. economic growth. As most of the variables have accepted the null hypothesis, it indicates the fact that the unit root is present in this series and data collected is nonstationary. When the first difference is applied, it was observed that all of the variables have now rejected the null hypothesis which clearly indicates that there is no unit root in first difference series and the data is stationary. It must be noted here that the non-stationary data in level series has shifted to stationary data in first difference series. This evident shift is basically caused due to the application of first difference. So in order to conclude the results of LLC unit root tests, it can be stated that data in level series is non stationary and becomes stationary in the first difference series.

Table 3. LLC unit root

Constructs	REP	REC	RDE	EG	PCI	SD
Level	-2.287	-2.327	-4.359	-2.237*	-2.483	-5.485
1st difference	-3.384**	-6.398***	-8.385***	-4.584***	-9.459***	-10.498**

4.2 Results of PCSE and GMM Test

As PCSE and GMM tests were used in order to resolve the issues of heteroscedasticity and cross-sectional dependence of the variables, the results of these tests have been presented in the table 4 of the study. It can be clearly seen in the table that renewable energy production has significant impact on sustainable development in accordance with both PCSE and GMM tests. With one percent increase in REP, the sustainable development increases by 28.3%. In the same fashion, the impact of renewable energy consumption on sustainable development has been found as significant by both the applied tests. With one percent increase in REC, the sustainable development increases by 19.3%. The last independent variable, R&D expenditure is also found to have significant impact on sustainable development and with one percent increase in RDE, the sustainable energy is supposed to be increased by 12.8%. In the last, the impact of one control variable, economic growth has been considered as significant while the impact of the other control variable, per capita income has been found as insignificant. These results can be concluded in such a way that the impact of REP, REC, RDE and economic growth on sustainable development is significant.

Table 4. Results from PCSE estimation

Dependent Variable = SD	PCSE estimation	Sys-GMM estimation
REP	0.291** (0.276)	0.283** (0.484)
REC	0.204* (0.492)	0.193** (0.988)
RDE	0.139** (0.687)	0.128* (0.959)
EG	0.293** (0.371)	0.278** (0.287)
PCI	0.043 (0.248)	0.038 (0.738)
Constant	0.736** (0.998)	0.609** (0.947)

R^2	0.792*** (0.974)	-
<i>No. of observations</i>	250	-
<i>No. of instruments</i>	-	248
<i>No. of observations</i>	-	248
<i>Arellano-Bond test for AR (1) (Pr W z)</i>	-	0.039
<i>Arellano-Bond test for AR (2) (Pr W z)</i>	-	0.382
<i>Hansen test of overid restrictions</i>	-	1.184

5. Discussion and Conclusion

5.1 Discussion

From the earlier sections of this study, it has been very clear that this study is aimed to find out and study the impact of renewable energy production and consumption and R&D expenditure on sustainable growth along with two control variables i.e. economic growth and per capita income. Three basic hypotheses were developed in order to study the above-mentioned impact. The first hypothesis was that renewable energy production has significant impact on sustainable energy and this hypothesis was accepted by the results of different tests. This result has also been shown in the past study (Johansson, Kelly, Reddy, & Williams, 1993). The next hypothesis was that renewable energy consumption has significant impact on sustainable energy. This hypothesis was also accepted according to the results. This is also in accordance with the past study (Klass, 1998). The last hypothesis was that R&D expenditure has significant impact on sustainable development and this hypothesis was also accepted by the results of the study. This behavior has been shown by another researcher in a past study (Guellec & Van Pottelsberghe De La Potterie, 2003). Aside from these hypotheses, the impact of a control variable, economic growth has also been considered as significant in context of sustainable development which is completely in concordance with a past research (Queiroz, Turra, & Perez, 2006).

5.2 Conclusion

Renewable energy consumption and production as well as R&D expenditure are the aspects that are very important for any country in context of growth and development. The economy and different sectors depend on the above-mentioned aspects. This study has been designed in order to find out the impact of the above-mentioned aspects on sustainable development in the presence of economic growth and per capita income as control variables. For this purpose, the author has gathered data from Asian countries for 28 years. Several tests and techniques have been employed in order to analyze this data effectively. These tests include unit root test, diagnostic checks, PCSE and GMM tests for various purposes. The results of these tests indicate that all the independent variables mentioned above are found to have significant impact on sustainable development. In addition, the impact of a control variable, economic growth has also found to be significant but the other control variable, per capita income has insignificant impact on sustainable development. The author has discussed several implications and benefits of this particular study and certain limitations and research recommendations have also been given in order to improve them.

5.3 Implications

Many benefits in context of theory, practical and policy making have been identified by the author in this study. First of all, this study contains literature about the aspects such as the production and consumption of renewable energy as well as R&D expenditure. This literature might help the other researchers in their studies in one way or

the other. In addition, the energy related business and departments may get assistance from this study in order to make their services efficient so that that sustainable development may be increased in the country. The policy and regulations making authorities and officials may also get guidance from this study while making policies favorable for increase in sustainable development of the country.

5.4 Limitations and Future Research Indications

First of all, the sample size of the data is very limited. Moreover, the study revolves around only some specific approaches and techniques for the analysis of collected data. In addition, the study is limited to only Asian countries. Another point in this regard is that the study is based on a few variables of specific categorization. The future researchers may look for other countries as well and use tests and approaches other than those used in this study. Finally, they may also increase the data sample size and may move to some other variables to include in their research.

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