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Assessment of Best Performing Top 10 Economies Based on OECD Green Growth Indicators: Using AHP, TOPSIS and Regression

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Abstract: ***Rapid economic growth is often accompanied by environmental depletion. Recent years have witnessed green growth as a renowned efficient approach to tracking the progress towards sustainable development. Green growth is imperative with the current energy depletion rate and environmental crisis. Green indicators and statistics can measure environmentally sustainable development; thus, they evaluate green growth and support its integration into policy. This study uses MCDM (Multi-criteria decision-making) techniques and OECD indicators for the world's top 10 economies to evaluate their green growth. This research aims to rank the top 10 economies according to green growth. The top-ranked best-performing country will be further analyzed to assess its renewable energy production.***
Keywords: AHP, green growth, Multi-criteria Decision Making (MCDM), TOPSIS.

I. INTRODUCTION

The accelerating pace of climate change has added another dimension of complexity to the relationship between economic growth and environmental degradation, leading to calls for policies to achieve a balance between the two. In addition to altering normal weather conditions, climate change will likely alter the frequency and intensity of extreme weather events, threatening human safety, health, and survival worldwide. Because of the common set of threats it poses on a global scale, a response to the challenge of climate change must emerge out of a common multilateral participative agenda, a worldwide resolve geared toward combating the effects of climate change.

Fossil fuel burning by the world's richest nations and their citizens' consumption habits cause half the global deaths from fine-particle pollution [1] G-20 countries make up nearly two-thirds of the global population, 80 percent of the world's economic output and three-quarters of international trade. They also have large environmental footprints when it comes to consumer products, with most developing countries manufacturing these goods and suffering the health impacts that arise from these operations [2]

Several countries and international organizations, such as the Organisation for Economic Co-operation and Development (OECD), World Bank, and United Nations, have developed strategies for green growth; others, such as the Global Green Growth Institute (GGGI), are specifically dedicated to the issue. To evaluate the performance of different countries, this paper takes the world's 10 top fastest-growing economies to find which fast-growing economy in the world is performing best in sustainable green growth

A. Identification of Suitable Green Growth Indicators

The assessment of the level of Green Growth is based on OECD Green Growth Indicators. These indicators are in the OECD Green Growth database (OECD 2017). It contains selected indicators for monitoring progress towards Green Growth. The database synthesizes data and indicators across a wide range of domains.

The indicators have been selected according to well-specified criteria and embedded in a conceptual framework, which is structured around five areas to capture the main features of the Green Growth

1) environmental and resource productivity and innovation;
2) natural assets (including biodiversity) and their cost-effective management;
3) the environmental quality of life (including access to basic services such as clean water);
4) related green growth policies, economic opportunities and social context of green growth; and
5) monitoring sustainability of overall economic developments, for example, through comprehensive wealth accounting

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Table 1 Indicators

Criteria	Sub-Criteria	Unit
CO_2 Productivity	Production-based Co_2 emissions	Million tonnes
Energy Productivity	Renewable energy, % total energy generation	Percentage
Land resources & forest resources	Natural & semi natural vegetated land, % total	Percentage
	Forests with long-term management plans, % total forest area	Percentage
Exposure to environmental risks	Mean population exposure to PM2.5	Micrograms per cubic meter
Socio-economic context	GDP	Million USD
Economic opportunities and policy responses	Development of related environmental technologies, invention per capita	Number

B. Literature Review

Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. (OECD 2017) The focus of green growth strategies is ensuring that natural assets can deliver their full economic potential on a sustainable basis. That potential includes providing critical life support services – clean air and water, and the resilient biodiversity needed to support food production and human health. Natural assets are not infinitely substitutable, and green growth policies consider that. Researchers like Meng Li have researched inclusive green growth in Asia-Pacific [3]. Saira Naseer has assessed green economic efficiency in china using AHP, and the research indicates that the AHP model reduces uncertainty and shortcoming in the evaluation process [4]. Research comparing the green economy in Iran with OECD countries strongly suggests using some other MCDM techniques such as AHP, ELECTRE, and Fuzzy MCDM [5]. Piwowarski Mateusz used TOPSIS and VIKOR methods to study sustainable development in EU countries [6]. To avoid developing unfavorably, “green growth” suggests pursuing such an economic development through which we can avoid degradation of the environment, loss of biodiversity, and unmanageable usage of natural resources (OECD, 2017). Green growth strongly emphasizes the fostering conditions needed to innovate, invest, and compete to stimulate economic growth without derailing resilient ecosystems [9].

Green growth is synonymous with renewable energy production. Despite the world's top economies being the main perpetrators of exploiting resources and the environment, their efforts towards green growth should be amplified. Previous researches lack the conceptual approach using MCDM techniques for assessing green growth while including renewable energy production. This research aims to evaluate the world’s top 10 economies using MCDM techniques, including AHP, TOPSIS, Simple moving average & Regression, while analyzing the best-performing country’s renewable energy production.

II. METHODS AND MODELS

A. Analytic Hierarchy Process (AHP)

In the decision-making theory, the analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions based on mathematics and psychology. Thomas L. Saaty developed it in the 1970s [7].

AHP follows the following steps,

1) The hierarchical process of the problem is formed.
2) Pair-wise comparisons are conducted for the criteria, sub-criteria, and alternatives.
3) Weights of pair-wise comparisons are calculated.
4) After calculating weights, decision matrixes are formed.
5) Final weights of alternatives obtain by multiplying decision matrixes from alternatives toward criteria.
6) Weights obtained in the last step are raw and must be normalized to be easily comparable.
7) Calculate the consistency ratio (CR). Correct the consistency of comparison. If CR is less than 0, the consistency is good. Otherwise, it is inconsistent. In this case, you need to adjust the comparison component to get good consistency.

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$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

Where (1) λmax is the average of the weighted sum vector divided by the corresponding standard, and n is the number of standards. RI is a random index.
In this research, the weight of each criterion is assigned from the 1-9 scale method. The judgment matrix is processed by Yaahp analytic processing software.

B. TOPSIS

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS is one of the most popular methods for multiple criteria decision-making, developed by Hwang and Yoon in 1981 [8] for solving a multiple attribute decision-making problem.

The stepwise procedure of Hwang and Yoon [8] for implementing TOPSIS is presented as follows:

1) Construct a normalized decision matrix of beneficial and non-beneficial criteria.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} x_{ij}^2}}, j = 1,2,3,\dots..,J; i = 1,2,3,\dots,n \quad (3)$$

Where x_{ij} and r_{ij} are original and the normalized score of the decision matrix, respectively

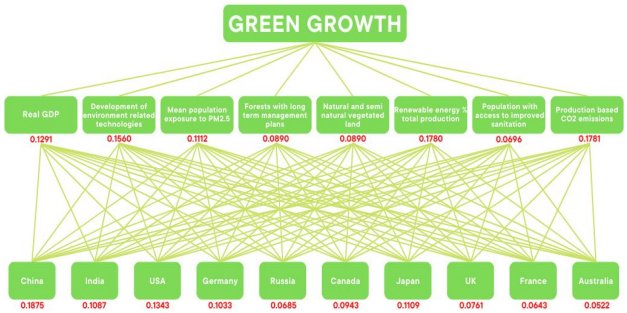
2) Construct the weighted normalized decision matrix by multiplying the weights w_i of evaluation criteria with the normalized decision matrix r_{ij}.

$$v_{ij} = w_i * r_{ij}, j = 1,2,3,\dots..,J; i = 1,2,3,\dots,n \quad (4)$$

3) Determined the positive ideal solution (PIS) and negative ideal solution (NIS)

$$A^* = \{v_1^*, v_2^* \dots\dots\dots\dots v_n^*\} \text{ maximum values} \quad (5)$$

4) Calculate the separation measures of each alternative from PIS and NIS



$$d_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, j = 1,2,\dots\dots..,J \quad (6)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, i = 1,2,\dots\dots..,J \quad (7)$$

5) Calculate the relative closeness coefficient to the ideal solution of each alternative

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1,2,\dots\dots,j \qquad (8)$$

6) Based on the decreasing values of the closeness coefficient, alternatives are ranked from most valuable to worst. The alternative having the highest closeness coefficient (CCi) is selected. To facilitate the TOPSIS calculation, this research has used Microsoft Excel.

C. Simple Moving Average

A simple moving average (SMA) is an arithmetic moving average calculated by adding recent values and dividing that figure by the number of periods in the calculation average.

$$SMA = \frac{A_1 + A_2 + A_3 \dots\dots\dots A_n}{n}, \qquad (9)$$

Where A is the value and *n* is the total number of periods.

D. Regression

Regression analysis is one of the most popular techniques for predictive modeling. A multiple regression model with more than one explanatory variable may be written as,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \varepsilon \qquad (10)$$

Where y is the output variable, β_i the regression parameters

(i =0,1,2…p), x_i the input variables (i =0,1,2…p) and ε the random error term. This research uses Microsoft Excel for calculating regression.

III. RESULTS AND CALCULATION

A. AHP Results

The first approach to evaluate the green growth in this paper was to calculate a pair-wise comparison matrix. The pair-wise comparison matrix was calculated using Yaahp software. The salary scale used for the pair-wise comparison matrix is based on the expert's opinions and literature. A scale of 1-7 is used for each criterion to score the matrix. Then using this matrix, the hierarchal evaluation of the matrix is constructed using Yaahp software.

From AHP, we determine the weights for each criterion which will be used for further calculation. The consistency ratio of the calculation is below 0.1.

Fig.1. AHP

According to the results gained from AHP, renewable energy production and production-based CO_2 emission have received the greatest weight for the case of green growth.

B. TOPSIS Results

The data obtained from AHP using 8 criteria and 10 top countries- China, India, USA, Germany, Russia, Canada, Japan, UK, France and Australia- are being used as weights for the TOPSIS model.

The matrix was formed at the first standard decision, as shown below.

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Table 2 Standard Decision Matrix

Country	GDP	Development of related environmental technologies	Mean population exposure to PM2.5	Forests with long-term management plans	Natural & semi-natural vegetated land	Renewable energy, % total energy generation	Production-based Co2 emissions	Population with access to sanitation
China	0.69642085	0.048987671	0.47564760	0.314024	0.244012	0.26624176	0.86527282	0.26830773
India	0.27737408	0.004399378	0.83017080	0.329193	0.120139	0.19747411	0.20237572	0.17361088
US	0.6023881	0.2731181	0.07649692	0.303211	0.354889	0.17326231	0.41565784	0.38667879
Germany	0.12607582	0.570254537	0.11556640	0.297787	0.225140	0.3968782	0.05643011	0.38273309
Japan	0.16159429	0.656101863	0.13600472	0.448606	0.326271	0.17728535	0.09253221	0.31960185
Canada	0.05235476	0.223179267	0.07065858	0.272982	0.377279	0.65376909	0.05002567	0.33143896
Russia	0.11408855	0.007253029	0.1173685	0.448569	0.402959	0.17350243	0.14370794	0.24068782
UK	0.09119069	0.192621424	0.09987399	0.270851	0.306678	0.37055357	0.02998307	0.38667879
France	0.08817074	0.257779728	0.11327661	0.202708	0.254214	0.19725126	0.02574532	0.31171045
Australia	0.03654228	0.117950897	0.06725174	0.144819	0.432726	0.19344731	0.03335655	0.29192134

A weighted normalized matrix is calculated using the weights obtained from the AHP method based on the matrix formed. The weighted normalized matrix will calculate the positive ideal solution (PIS) and negative ideal solution (NIS).
The weighted decision matrix is as follows

Table 3 Weighted Decision Matrix

Country	GDP	Development of related environmental technologies	Mean population exposure to PM2.5	Forests with long-term management plans	Natural & semi-natural vegetated land	Renewable energy, % total energy generation	Production-based Co2 emissions	Population with access to sanitation
China	0.08990793	0.007642077	0.05289201	0.027948	0.021717	0.04739103	0.15410509	0.01867421
India	0.03580899	0.000686303	0.09231499	0.029298	0.010692	0.03515039	0.03604312	0.01208331
US	0.0777683	0.042606432	0.00850646	0.026985	0.031585	0.03084069	0.07402866	0.02691284
Germany	0.01627639	0.088959708	0.01321794	0.026503	0.020037	0.07064433	0.01005 02	0.02663822
Japan	0.02086182	0.102351891	0.01512373	0.039925	0.029038	0.03155679	0.01647999	0.02224428
Canada	0.006759	0.034815966	0.00785724	0.024295	0.033577	0.11637089	0.00890957	0.02306815
Russia	0.01472883	0.001131473	0.01305139	0.039922	0.035863	0.03088343	0.02559438	0.01675187
UK	0.01177272	0.030048942	0.01110592	0.024105	0.027294	0.06595853	0.00533999	0.02691284
France	0.01138284	0.040213646	0.01259636	0.018041	0.022625	0.03511072	0.00458524	0.02169504
Australia	0.00471761	0.018400 34	0.00747873	0.012888	0.037711	0.03443362	0.00594 08	0.02032194

The PIS and NIS are calculated based on each alternative's desired outcome. The criteria of "Mean Population Exposure To PM2.5" and "Production-based CO2 Emissions" is used as a negative index in NIS and PIS as emission and exposure to pollution are expected to be less in an ideal case and much in the ideal negative case. In the last step, the Euclidean distance formula compares each alternative distance to PIS and NIS. Based on the similarity index, a ranking is made. The following table shows the ranking of each alternative with respective similarities to PIS and NIS

Table 4 Ranking of Alternatives

	GDP	Development of related environmental technologies	Mean population exposure to PM2.5	Forests with long-term management plans	Natural & semi-natural vegetated land	Renewable energy, % total energy generation	Production-based Co2 emissions	Population with access to sanitation
Ideal	0.08990793	0.102351891	0.00747873	0.039925	0.037711	0.11637089	0.00458524	0.02691284
Neg Ideal	0.00471761	0.000686303	0.09231499	0.012888	0.010692	0.03084069	0.15410509	0.01208331

The TOPSIS result concludes that Germany performs best in terms of green growth, followed by Canada and Japan, among the top 10 economies in the world.

Table 5 Ranking of Countries

Ranking	Country	Ci
1	Germany	0.67929936
2	Canada	0.64084863
3	Japan	0.63363883
4	UK	0.59787304
5	France	0.57015861
6	Australia	0.5409844
7	US	0.53572777
8	Russia	0.50259878
9	India	0.41943273
10	China	0.33185364

Germany is one of the best-performing countries in green growth, while the renewable energy production criteria ranked the most important among the criteria for green growth. This research forecasts gross electricity production and evaluates the correlation between renewable sources and total electricity production. This research aims to evaluate the correlation between Renewable energy sources and Gross Electric production in Germany. And to Forecast Renewable production and gross Electricity Production. The data used in this section is from 2013-2021 for hydro, wind, solar, biomass and total energy production shown below.

Table 6 Energy Data

Year	Hydro Power (GWH)	Wind (GWH)	Solar (GWH)	Biomass (GWH)	Energy production (GWH)
2013	27353	38547	11729	33923	587500
2014	23512	49858	19599	36890	570100
2015	27849	51680	26380	43203	584600
2016	28782	52737	31010	45514	594800
2017	25444	58497	36056	48288	584400
2018	24897	80624	38726	50326	604700
2019	26134	79924	38098	50929	609200
2020	26155	105693	39401	50916	614100
2021	24144	109951	45784	50880	600500

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C. Simple Moving Average Results

The simple moving average is used to forecast the data for the renewable energy source. The data is forecasted till 2024, as shown in table 7.

Table 7 Forecasted Energy Data

Year	Hydro Power (GWH)	Wind (GWH)	Solar (GWH)	Biomass (GWH)
2013	27353	38547	11729	33923
2014	23512	49858	19599	36890
2015	27849	51680	26380	43203
2016	28782	52737	31010	45514
2017	25444	58497	36056	48288
2018	24897	80624	38726	50326
2019	26134	79924	38098	50929
2020	26155	105693	39401	50916
2021	24144	109951	45784	50880
2022	25477.67	98522.6	41094.3	50908.3
2023	25149.5	107822	42592.5	50898
2024	24144	109951	45784	50880

D. Regression Results

Regression Statistics

Multiple R	0.953565173
R Square	0.90928654
Adjusted F	0.818573079
Standard E	5994.90273
Observatio	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressio	4	1440964565	360241141.3	10.02372234	0.02319385
Residual	4	143755435	35938858.75		
Total	8	1584720000			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	388497.8406	46994.36996	8.266901777	0.001168314	258020.552	518975.129	258020.5521	518975.129
Hydropow	2.20237545	1.62349037	1.356568225	0.246431287	-2.3051564	6.709907341	-2.30515644	6.709907341
wind	0.585648251	0.1736907	3.37178818	0.027997334	0.10340556	1.067890946	0.103405556	1.067890946
solar	-2.617807666	1.261668439	-2.074877666	0.106639434	-6.1207608	0.885145495	-6.12076083	0.885145495
bio fuels	4.187979513	1.916700987	2.184993664	0.09421732	-1.1336356	9.509594588	-1.13363556	9.509594588

The data from table 7 is used to perform regression. The regression shows that solar energy production negatively impacts total energy production whereas hydro power energy has the greatest positive impact on total energy production. Using equation (10), regression is done to forecast the total energy production, as shown below.

Table 8 Final Regression Results

Year	Hydro Power (GWH)	Wind (GWH)	Solar (GWH)	Biomass (GWH)	Electricity production(forecast) (GWH)
2013	27353	38547	11729	33923	582678.9623
2014	23512	49858	19599	36890	572667.4944
2015	27849	51680	26380	43203	591973.6088
2016	28782	52737	31010	45514	592205.4264
2017	25444	58497	36056	48288	586635.2288
2018	24897	80624	38726	50326	599934.724
2019	26134	79924	38098	50929	606418.4435
2020	26155	105693	39401	50916	618090.8161
2021	24144	109951	45784	50880	599295.2957
2022	25477.67	98522.6	41094.3	50908.3	607934.8518
2023	25149.5	107822	42592.5	50898	608693.0559
2024	24144	109951	45784	50880	599295.2957

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IV. CONCLUSION

In this research, we have considered the world's top 10 best-performing economies. Global warming and climate change are serious issues. It is noted that the impact made by top economies on climate and environment is higher than the developing nations. Hence the leaders of world economies should focus on green growth.

This research is divided into two objectives. The initial part of the research focuses on ranking the top 10 best performing economies based on OECD indicators using AHP and TOPSIS. This study aims to introduce a novel approach based on AHP and TOPSIS to rank and evaluate the indicators of green growth into sustainable growth. A combination of AHP and TOPSIS models has been used to evaluate and rank the green growth indicators based on experts' opinions and literature review. In this regard, six indicators and seven sub-indicators are collected from the existing green growth literature. The data for evaluating green growth is collected from OECD Statistics. The results from AHP indicate that renewable energy production and production-based CO_2 emission carry the highest value in green growth. The obtained weights from AHP were used in TOPSIS analysis, indicating that Germany is the best performing nation in green growth while India and China rank the lowest among the top 10. These results are consistent with the OECD annual report as most countries have set up targets to decrease emissions and increase the use of renewable sources by 2030; Germany is the only country in the OECD vision 2030 which is performing well along its set targets.

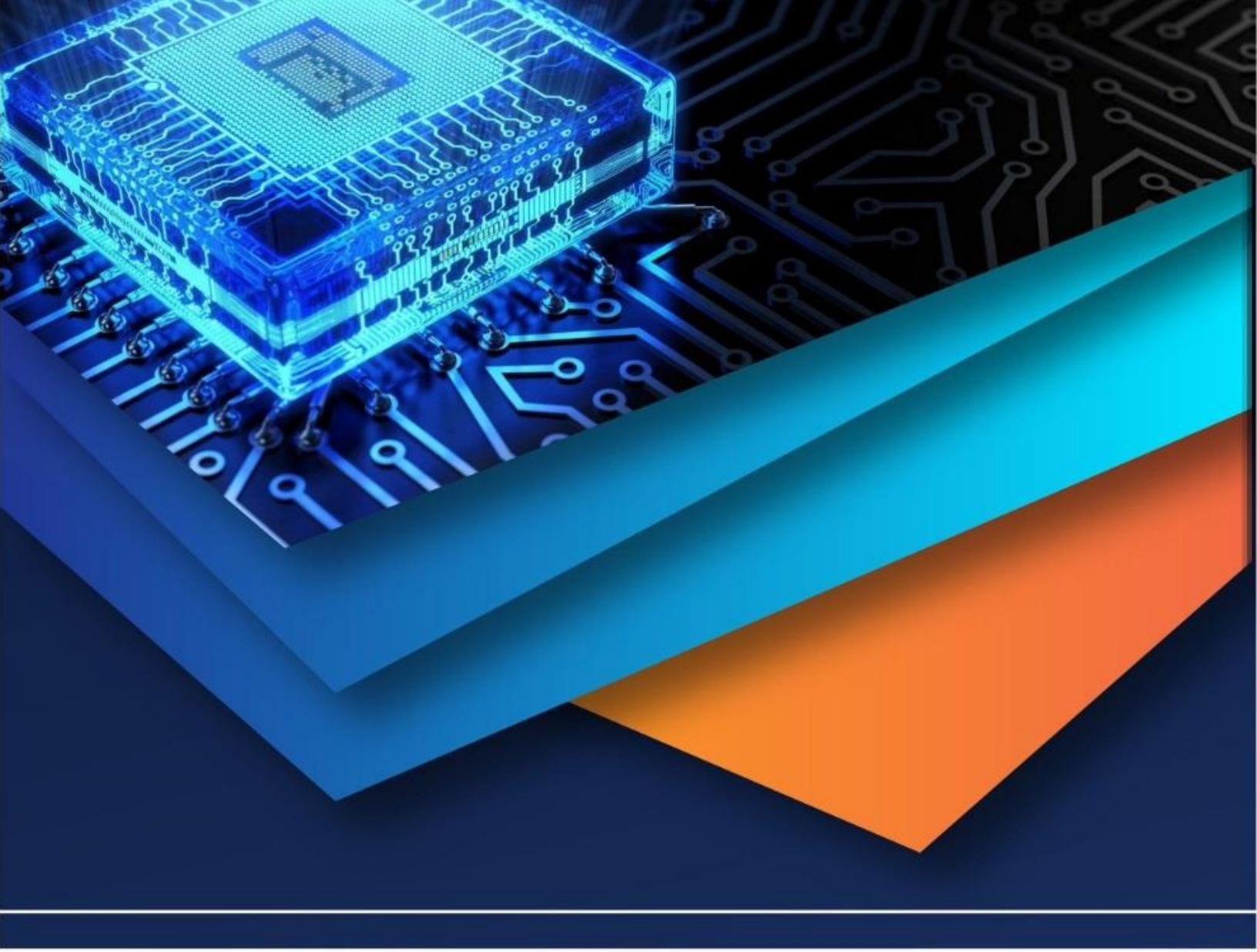
The second part of the thesis focuses on the energy production of Germany and correlates renewable sources and total energy production. And forecast renewable production and gross production. Simple moving averages and regression has been used for this task. Using a Simple moving average, the renewable energy production is forecasted and used in the formulated equation driven by the regression. This result shows that solar energy production negatively impacts Germany's total energy production. This research suggests that for Germany to improve further towards green growth, it should focus on hydropower and biofuels.

Despite the study's strengths, some limitations can be opportunities for future work. First, this study evaluated the green growth indicators in only the top 10 economies, but the factor of developing nations and developed nations is not considered in this study; therefore, future works would extend this method in evaluating the factors and differences between the developing countries and developed countries. Secondly, performance measurement on green growth for both sustainable performance and operational performance can be considered the critical drivers for ascertaining the success and failure of green growth. Therefore, future studies would measure green growth indicators based on different performance measurements [10], such as the Global Reporting Initiative (GRI) sustainable performance measurement. This study used the quantitative approach for evaluating green growth indicators; therefore, the integration of qualitative research and quantitative research will strengthen the study results to clarify the impacts of green growth policy on the practices.

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