Effect of Economic Growth on Renewable Energy Generation

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INTRODUCTION

- Fossil fuels still account for more than 80 percent of global energy production, but cleaner sources of energy are gaining ground. About 29 percent of electricity currently comes from renewable sources.

- Most of the global population lives in countries that are net-importers of fossil fuels -- that's about 6 billion people who are dependent on fossil fuels from other countries, which makes them vulnerable to geopolitical shocks and crises.

- The rapid transition to renewable energy will be good for people and the planet. But the land-use footprint for this buildout will be large because renewable energy infrastructure requires a lot of land

So, What factors play a role in a nation's transition towards renewable energy sources?

Dataset

Source: https://ourworldindata.org/grapher/

Time period: 1990 to 2020

Countries covered: Algeria, Australia, Austria, Azerbaijan, Bangladesh Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Cyprus, Czechia, Denmark, Ecuador, Egypt, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Kazakhstan, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Morocco, Netherlands, North Macedonia, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States, Uzbekistan, Venezuela, Vietnam

Model 1

Dependent variable:

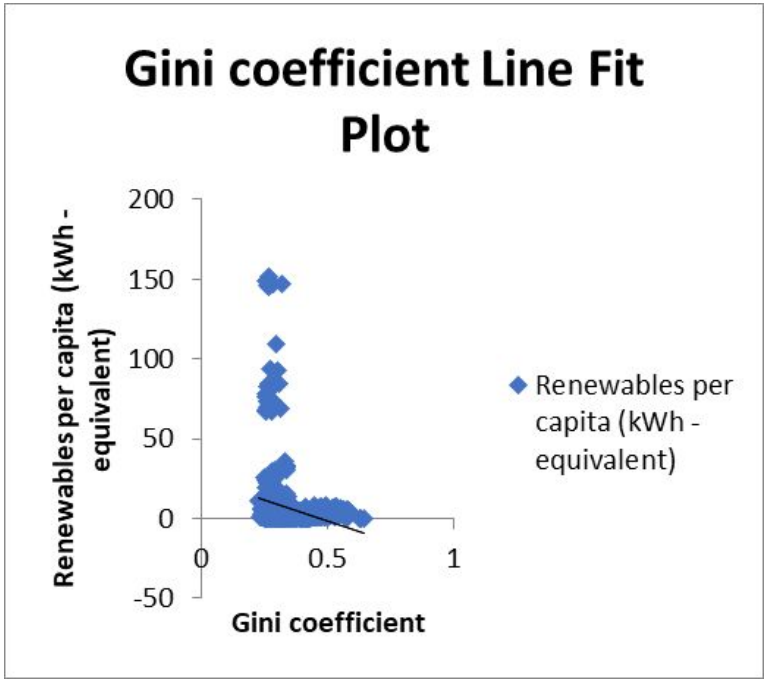
- Per capita generation of renewable energy - indicates sum of energy from hydropower, wind, solar, geothermal, wave and tidal, and bioenergy.

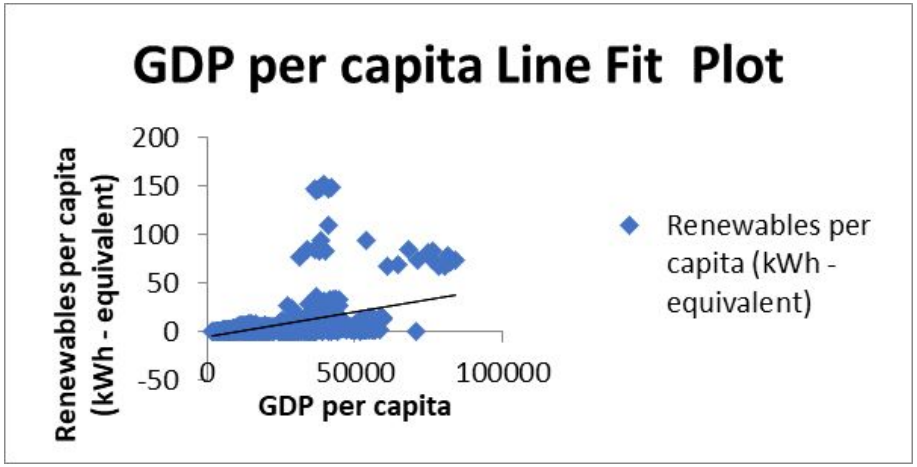
Independent variables:

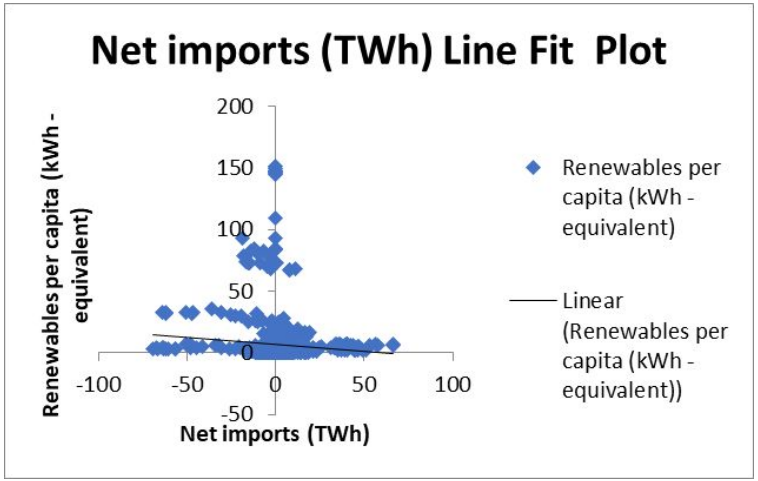
- Gini coefficient (~ measure of inequality),
- Primary energy consumption (total energy demand) per capita (kWh/person),
- GDP per capita,
- Human Development Index (UNDP),
- Average Total Years of Schooling for Adult Population,
- Net import of energy (in TWh),
- Oil production per capita (kWh),
- Urban population (% of total population)

Model: $Y= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon$

Linear Fit Plots







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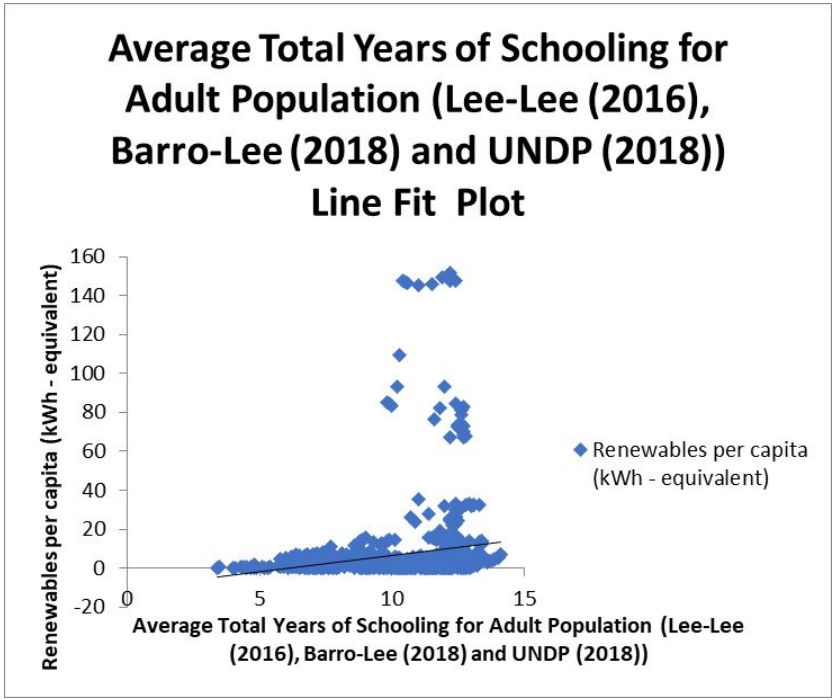

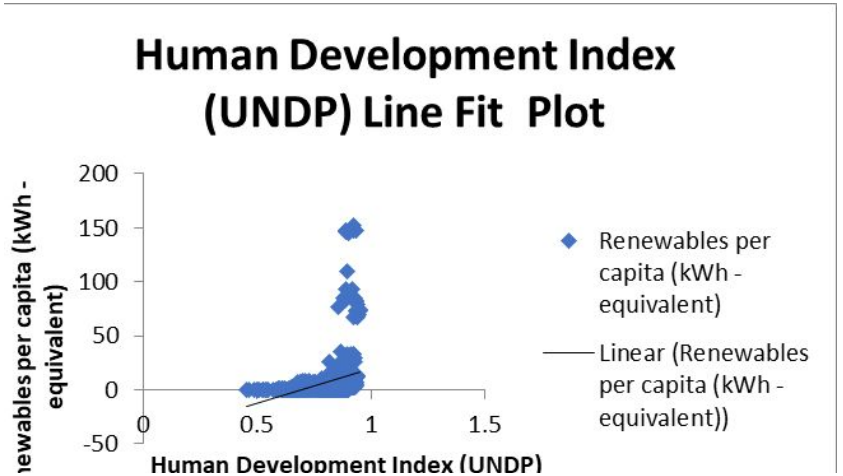

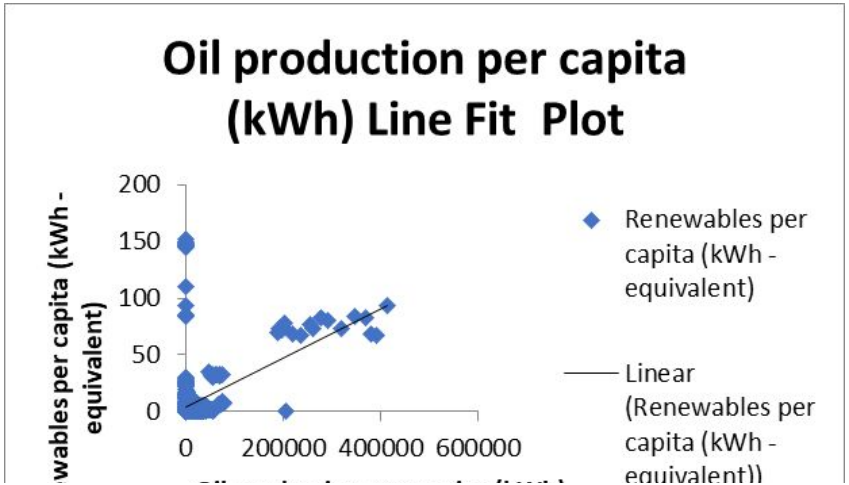

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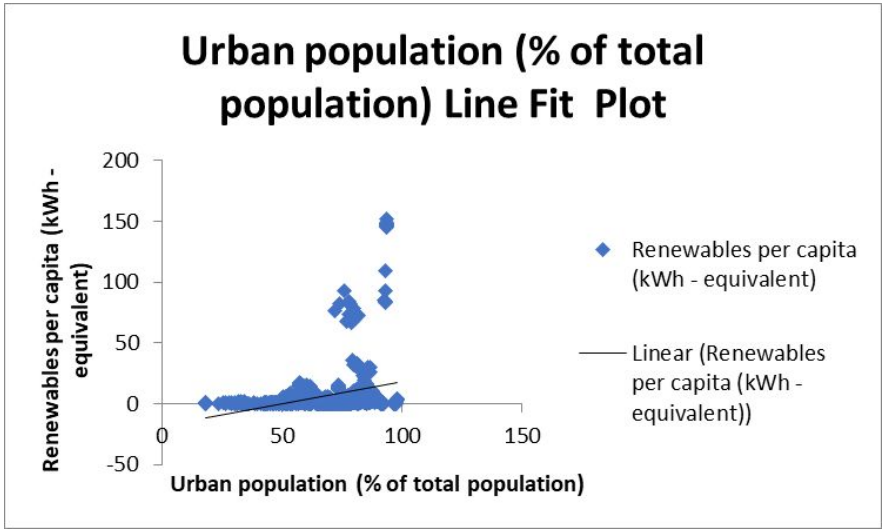
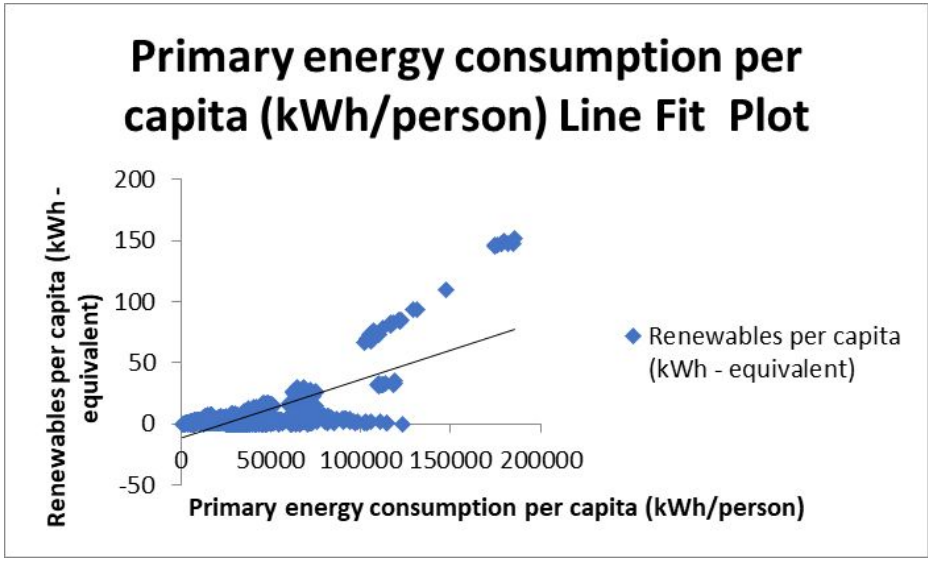




Results

	Estimate	SE	tStat	pValue
(Intercept)	-30.438	7.0642	-4.3088	1.8209e-05
HumanDevelopmentIndex_UNDP_	80.575	12.601	6.3942	2.5795e-10
GDPPerCapita	-0.00051789	6.2504e-05	-8.2857	4.1949e-16
AverageTotalYearsOfSchoolingForAdultPopulation_Lee_Lee_2016__Ba	-2.9092	0.33586	-8.6619	2.1008e-17
PrimaryEnergyConsumptionPerCapita_kWh_person_	0.00064099	2.2013e-05	29.118	3.8989e-132
UrbanPopulation__OfTotalPopulation_	-0.23546	0.037942	-6.2057	8.2734e-10
GiniCoefficient	14.643	6.4326	2.2763	0.02306
NetImports_TWh_	-0.0099089	0.026208	-0.37808	0.70546
OilProductionPerCapita_kWh_	0.00012438	1.0866e-05	11.446	1.9724e-28

- $R^2 = 0.652$
- Adjusted R-squared= 0.649
- F-statistic vs. constant model: 212, p-value = 1.61e-201

Model 2 - Excluding *net import of energy* parameter

Dependent variable:

- Per capita generation of renewable energy - indicates sum of energy from hydropower, wind, solar, geothermal, wave and tidal, and bioenergy.

Independent variables:

- Gini coefficient (~ measure of inequality),
- Primary energy consumption (total energy demand) per capita (kWh/person),
- GDP per capita,
- Human Development Index (UNDP),
- Average Total Years of Schooling for Adult Population,
- Oil production per capita (kWh),
- Urban population (% of total population)

Model: $Y= \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \varepsilon$

Results from the new model

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	-30.358	7.0577	-4.3014	1.881e-05
HumanDevelopmentIndex_UNDP_	80.419	12.589	6.3883	2.6758e-10
GDPPerCapita	-0.00052041	6.2117e-05	-8.3779	2.0311e-16
AverageTotalYearsOfSchoolingForAdultPopulation_Lee_Lee_2016__Ba	-2.8927	0.33286	-8.6904	1.6643e-17
PrimaryEnergyConsumptionPerCapita_kWh_person_	0.00064171	2.1921e-05	29.274	3.4185e-133
UrbanPopulation__OfTotalPopulation_	-0.23573	0.037918	-6.2167	7.7296e-10
GiniCoefficient	14.39	6.3949	2.2503	0.024669
OilProductionPerCapita_kWh_	0.00012485	1.0791e-05	11.569	5.6689e-29

- $R^2 = 0.652$
- Adjusted R-squared= 0.649
- F-statistic vs. constant model: 242, p-value = 1.07e-202

➔ Likelihood ratio test: **p-value** = **0.7040**

- Cannot reject the null hypothesis “the smaller model provides as good a fit for the data as the larger model”

Multicollinearity

Variance Inflation Factor

Predictor	VIF
Human Development Index	**9.7034**
GDP per capita	**6.3721**
Average Total Years Of Schooling For Adult Population	**3.5152**
Primary Energy Consumption Per Capita	**2.8224**
Urban Population Of Total Population	**2.1992**
Gini coefficient	**1.6034**
Oil Production Per Capita	**1.4206**

Multicollinearity

	Gini coefficient	*Primary energy consumption*	*GDP per capita*	*Human Development Index*	*Average Total Years of Schooling*	*Oil production*	*Urban population*
Gini coefficient	1						
Primary energy consumption	-0.3940222	1					
GDP per capita	-0.356764874	0.740127353	1				
Human Development Index	-0.397206094	0.658688696	**0.862048986**	1			
Average Total Years of Schooling	-0.466039079	0.529390919	0.631544974	**0.813038003**	1		
Oil production per capita	-0.073532309	0.370584474	0.379030796	0.160054104	0.13994542	1	
Urban population	0.004686202	0.565026001	0.547594575	0.620245657	0.428382352	0.117172862	1

Model 3- Excluding *Human Development Index*

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	8.5301	3.6487	2.3379	0.019611
GDPPerCapita	-0.00022981	4.3216e-05	-5.3178	1.3226e-07
AverageTotalYearsOfSchoolingForAdultPopulation_Lee_Lee_2016__Ba	-1.4942	0.25617	-5.8327	7.5752e-09
PrimaryEnergyConsumptionPerCapita_kWh_person_	0.00062782	2.2286e-05	28.172	5.1139e-126
UrbanPopulation__OfTotalPopulation_	-0.149	0.036171	-4.1192	4.148e-05
GiniCoefficient	11.185	6.5133	1.7172	0.086285
OilProductionPerCapita_kWh_	0.00010272	1.0442e-05	9.8376	9.0453e-22

Number of observations: 916, Error degrees of freedom: 909
Root Mean Squared Error: 11.6
R-squared: 0.636, Adjusted R-Squared: 0.634
F-statistic vs. constant model: 265, p-value = 1.54e-195

- ➔ Likelihood ratio test: **p-value** = **2.1429e-10**
  - ◆ Can reject the null hypothesis “the smaller model provides as good a fit for the data as the larger model”

Change in Multicollinearity

Predictor	**VIF**
GDP per capita	**2.9548**
Average Total Years Of Schooling For Adult Population	**1.9947**
Primary Energy Consumption Per Capita	**2.7946**
Urban Population Of Total Population	**1.9173**
Gini coefficient	**1.5935**
Oil Production Per Capita	**1.2743**

Model 4- Excluding *Gini coefficient*

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	12.841	2.6505	4.8448	1.4895e-06
GDPPerCapita	-0.00023448	4.3201e-05	-5.4276	7.3301e-08
AverageTotalYearsOfSchoolingForAdultPopulation_Lee_Lee_2016__Ba	-1.6507	0.23982	-6.8831	1.0904e-11
PrimaryEnergyConsumptionPerCapita_kWh_person_	0.00061596	2.1221e-05	29.025	1.3219e-131
UrbanPopulation__OfTotalPopulation_	-0.12404	0.033174	-3.7392	0.00019616
OilProductionPerCapita_kWh_	0.00010503	1.0373e-05	10.125	6.6697e-23

Number of observations: 915, Error degrees of freedom: 909
Root Mean Squared Error: 11.6
R-squared: 0.635, Adjusted R-Squared: 0.633
F-statistic vs. constant model: 316, p-value = 6.28e-196

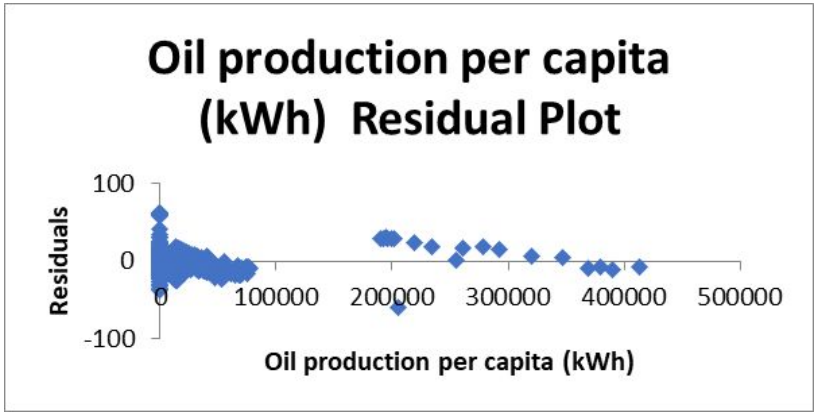
- ➔ Likelihood ratio test: **p-value** = **4.1830e-10**
  - ◆ Can reject the null hypothesis “the smaller model provides as good a fit for the data as the larger model”

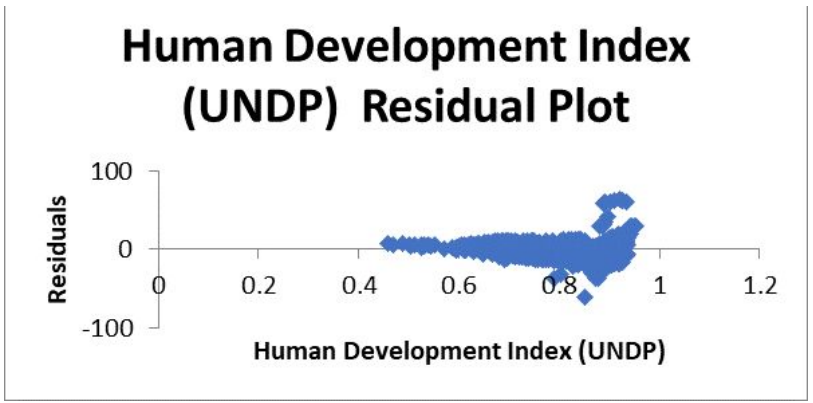
Heteroskedasticity

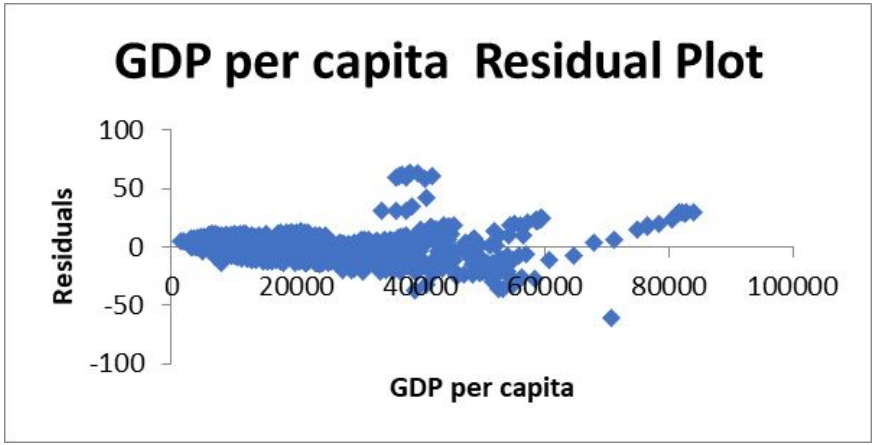
- **Breusch-Pagan test** ~ Chi-Square test statistic $\chi 2$ as $n*R^2_{new}$, where n= number of observations, R^2_{new}: The R-squared of the model that uses the squared residuals as the response values

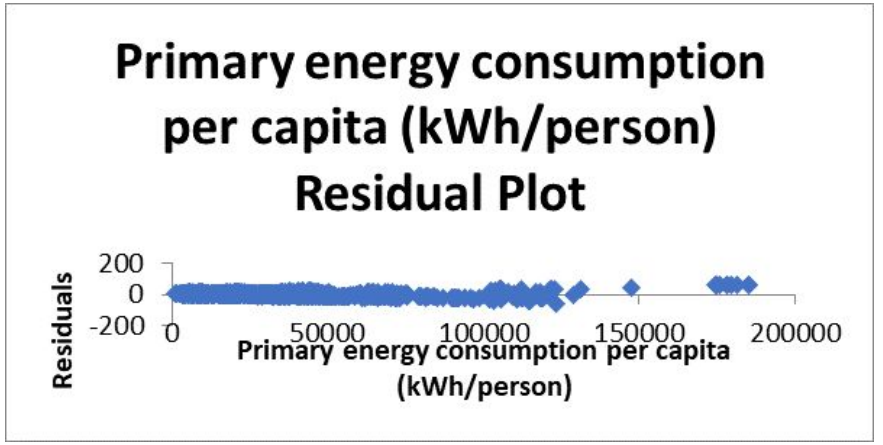
    - p-value < 0.05 → Heteroskedasticity present

Residual Plots









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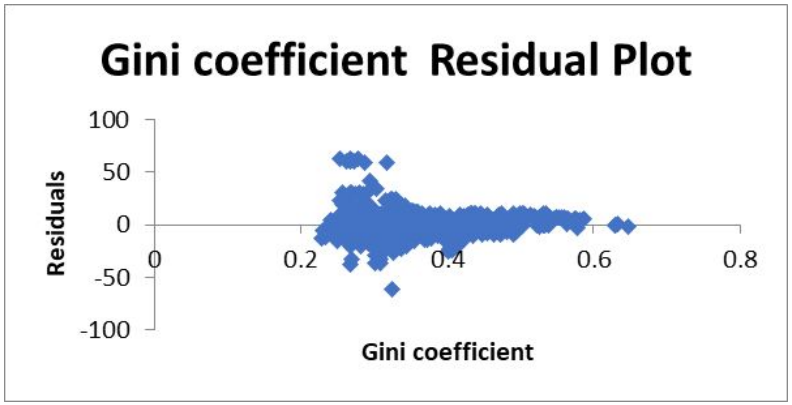

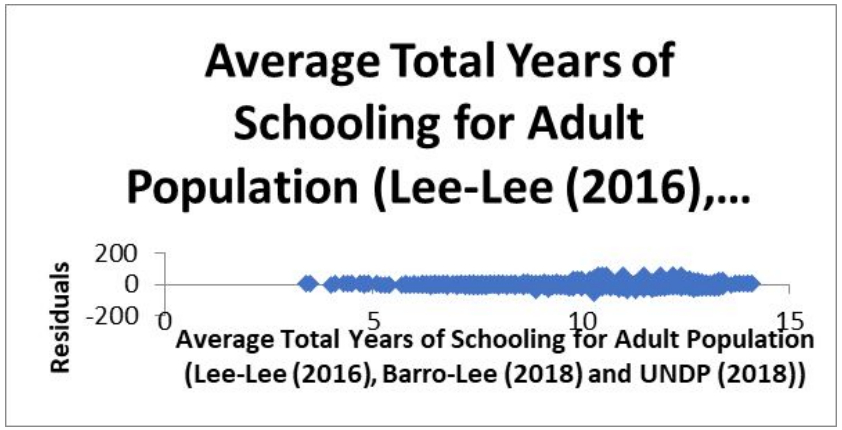

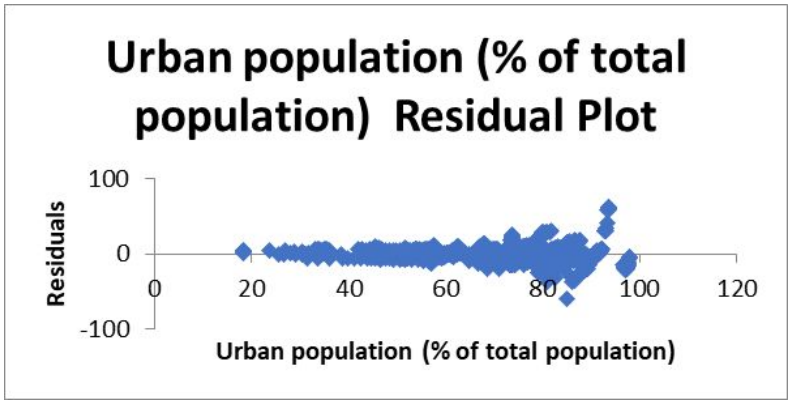

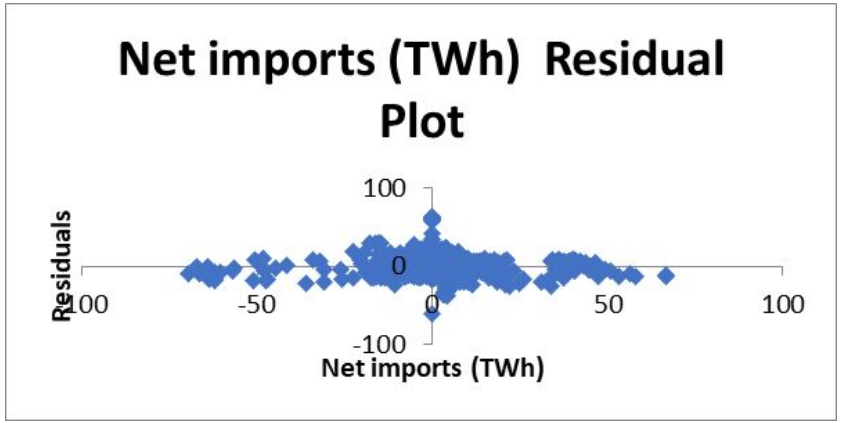

CONCLUSION

- Gini coefficient ~ income or wealth inequality→ found to be significant
  - Bridging income inequality can increase renewable energy consumption
- Net import of energy ~ energy use-production→ did not appear to play a significant role
- Biggest hurdles to renewable energy generation are capital costs
  - A possible explanation behind why renewable energy generation does not increase with increase in GDP as countries rely on non-renewable sources for quicker and more impressive economic growth.
- Urbanisation has negative effect on renewable energy consumption.

➔ The model did not include impact of oil and fuel prices on renewable energy demand.

References

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