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Factors Driving Renewable Energy Consumption: Air Pollution and Governance

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Abstract

Nations around the world are adopting renewable energy at varied paces. While some countries have a relatively higher consumption of renewable energy, others are still heavily dependent on traditional sources to meet their energy needs. But what exactly are the factors driving this shift towards renewable energy? Probably the first answer that comes to the mind is that nations have different potentials to generate renewable versus conventional energy. But beyond the obvious, there are other factors influencing renewable energy consumption. This research paper makes an attempt to establish two such factors: pollution level and type of governance. Using several regression models, it aims to show that nations that hold governments accountable to the citizens and have large scale pollution are the ones showing a faster shift towards renewable energy.

Keywords

pollution, renewable, energy, factors affecting renewable energy, energy consumption, government, pm2.5, renewable consumption

Disciplines

Agricultural and Resource Economics | Business | Environmental Studies | Social and Behavioral Sciences

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Introduction

Rising energy demands and depleting sources of conventional energy i.e. fossil fuels are no more unknown to the world. Over the past few years, developing capacities to meet the energy demand of residents has become one of the primary concerns of the governments across the globe. And under the shades of the energy crisis has blossomed the renewable energy market.

Nations around the world are transitioning towards energy generation from renewable sources at varied paces. While on one hand nations like Brazil and Norway have 43.79% and 57.72% respectively of their energy consumption needs being met through renewable energy sources (in 2015), nations like the Netherlands and Egypt are still highly dependent on fossil fuels with renewable energy consumption forming only 5.89% and 5.71% of total final energy consumption (*Renewable Energy Consumption | World Bank Data*). With these differences existing in renewable energy consumption emerges the question of what exactly are the factors driving the shift towards renewable energy?

Probably the first answer that comes to the mind is that nations have different potentials to generate renewable versus conventional energy. But beyond the obvious, there are other factors influencing renewable energy consumption. One such factor is pollution. Existing correlations between the pollution level of a country and its renewable energy consumption hint towards the idea of pollution level as a driving factor of renewable energy adoption.

While previous research has attempted to show CO_2 emissions as a factor of renewable energy, this paper considers another measure of pollution levels, namely PM2.5 to show the correlation between pollution levels and renewable energy consumption due to its direct impact on consumer health. Using several regression models, it aims to show that the level of pollution in a country is also driving the shift towards renewable energy consumption.

Furthermore, the type of government functioning in the nation also influences renewable energy consumption. Nations that hold governments accountable to the citizens are the ones with higher renewable energy consumption.

Hence overall, nations that hold governments accountable to the citizens and have large scale pollution are the ones showing a faster shift towards renewable energy.

Understanding the Data

For the purpose of this study, the following datasets were used:

- **World Bank's Renewable Energy Consumption**
  This dataset is from a World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program. It measures renewable energy consumption as a percentage of total final energy consumption based on weighted averages. The renewable energy includes all major forms of renewable energy i.e. hydro, solar, wind, and biomass. The dataset provides figures for years 1990 to 2015 for 264 countries and regions.

- **PM2.5 air pollution**
  This data set is a result of Global Burden of Disease Study 2016 conducted by Brauer, M. et al. It provides the value of mean annual exposure of nations to PM2.5 in micrograms per cubic meter over the years 1990 to 2015 for 264 countries and regions. It has been calculated by weighing mean annual concentrations of PM2.5 by population.

  As Brauer, M. et al. define "population-weighted exposure to ambient PM2.5 pollution is defined as the average level of exposure of a nation's population to concentrations of suspended particles measuring less than 2.5 microns in aerodynamic diameter, which are capable of penetrating deep into the respiratory tract and causing severe health damage."

  PM2.5 suffers from some limitations which are essential to be known in the context of this study. The value of PM2.5 is sensitive to the local conditions and could potentially vary significantly even over short distances. Further, measurement protocols of the indicator differ from country to country.

  Despite the limitations, PM2.5 is widely used as an indicator of air quality. Further, the value of this indicator is available for most countries making cross-country comparisons feasible. Hence, it has been included in this study as an indicator of pollution level.

While previous research has made attempts to show Carbon dioxide (CO_2) emissions as a factor driving renewable energy consumption, this research uses PM2.5 as a measure of pollution. The reason behind studying PM2.5 is that PM2.5 levels result in a relatively direct impact on consumers. As world bank estimates show, exposure to polluted air caused about 7 million deaths in 2012. In 2015, World Bank added PM2.5 to its list of indicators as a measure of air pollution as PM2.5 leads to long-term impacts on lung and heart diseases. WHO also stated that PM2.5 is the best indicator of health risks caused due to air pollution levels ("WHO | Air Quality Deteriorating in Many of the World's Cities"). Since this paper is a study of consumption, factors that have a relatively direct impact on consumers are more likely to drive their decisions. As a result, this study includes PM2.5 in place of CO_2. Another reason for not including CO_2 is

that the carbon dioxide emissions may not reflect the true image of nations producing other greenhouse gases like methane and nitrous oxide. This is particularly true for agricultural economies (“Understanding Air Pollution and the Way It Is Measured”).

- **The World Factbook List of Government Types**
  This is a database maintained by Central Intelligence Agency that provides a list of the government type prevalent in different countries.

Overall, for the purpose of this study data from 2010 to 2015 was included. Furthermore, since this is a nation-wise study, figures for region-wise aggregates were not included. Hence, for this study, the data for 193 countries ranging from low-income to high income, covering different continents, demographics, and sizes was observed.

Literature Review

With ongoing global efforts to transition towards renewable sources of energy, the world's renewable energy consumption has increased significantly over the years. In 2015, 18.054% of Total Final Energy Consumption of the world comprised of renewable sources (*Renewable Energy Consumption | World Bank Data*). But with different social, economic, political, environmental and technological conditions, consumers across the globe are adopting renewable energy at varied rates. Ongoing research in the field of renewable energy involves efforts to identify the factors driving renewable energy consumption in different countries. While most researchers agree to the idea of income related factors driving renewable energy consumption, whether pollution in the form of CO_2 emissions is also affecting the consumption trend or not has been a debated topic.

Perry Sadorsky in his research paper titled "Renewable energy consumption and income in emerging economies" observed that increases in per capita GDP are positively correlated with per capita renewable energy consumption. Focused on emerging countries, his research shows that in the long run, a 1% increase in real income per capita increases the consumption of renewable energy per capita by nearly 3.5%. As Sadorsky accepted in his paper, several other researchers have also indirectly hinted towards a positive relationship between income and renewable energy consumption. These papers provide strong evidence to establish per capita income as a factor of renewable energy consumption (Sadorsky, "Renewable Energy Consumption and Income in Emerging Economies").

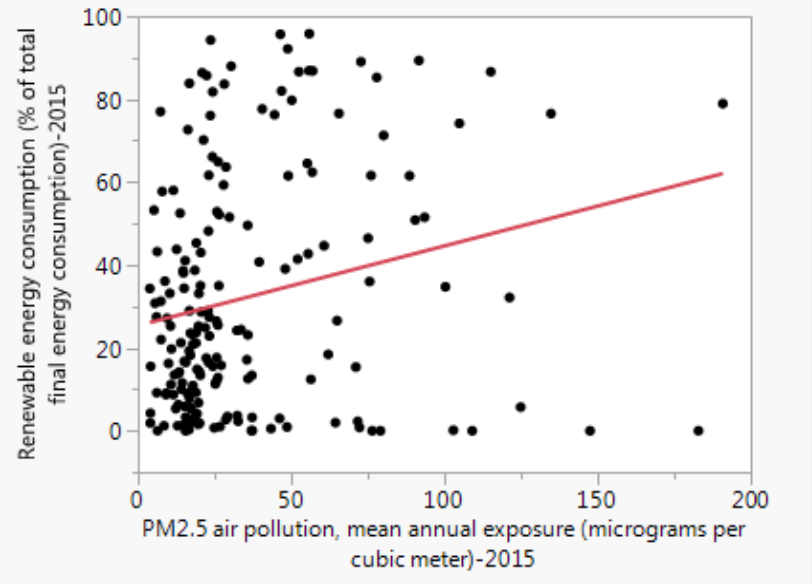
In another paper published in the same time period, Perry Sadorsky further identified pollution in terms of CO_2 per capita as a factor affecting renewable energy consumption. Limiting his research to the G7 countries, Sadorsky adopted a mathematical approach using panel cointegration techniques to calculate long-term CO_2 elasticities for renewable energy consumption. He showed that increase in carbon dioxide emissions per capita is one of the major drivers behind per capita renewable energy consumption (Sadorsky, "Renewable Energy Consumption, CO2 Emissions and Oil Prices in the G7 Countries").

At the same time, Jianbang Gan and CT Smith wrote that CO_2 reduction targets are not enough to motivate the switch from traditional to renewable energy sources. Gan and Smith's study was focused on the supply side of renewable energy in OECD countries. They showed that renewable energy and bioenergy market deployment policies and GDP were primary factors affecting per capita supply of renewable energy (Gan and Smith).

This paper takes the discussion of factors affecting renewable energy further ahead and brings in pollution in terms of PM2.5 as a driver of renewable energy consumption. It also shows the impact of government type on renewable energy consumption.

Pollution, Governance and Renewable Energy

Figure 1, below shows the correlation between pollution and renewable energy consumption. Overall, a positive correlation exists with a 4% Coefficient of Determination.



RSquare	0.047821
RSquare Adj	0.042589
Root Mean Square Error	27.89001
Mean of Response	32.17653
Observations	184

Figure 1: Renewable Energy Consumption Against Pollution Levels 2015

While the correlation factor is weak, some region wise observations of the correlation between renewable energy consumption and pollution further indicate a positive trend between pollution and consumption of renewable energy. Nations that have a high degree of pollution also have relatively higher consumption of renewable energy.

Table 1: Region Wise Renewable Energy Consumption Against Pollution

Region	**Mean PM2.5 (micrograms/m^3)**	**Mean Renewable Energy Consumption (%)**	**R Square**
South Asia	62.41545	45.21526086	0.267102
Sub-Saharan Africa	54.68665	64.56010329	0.102699
Latin America & Caribbean	19.59761	23.43838791	0.10242
East Asia & Pacific	20.04294	19.80705057	0.07281

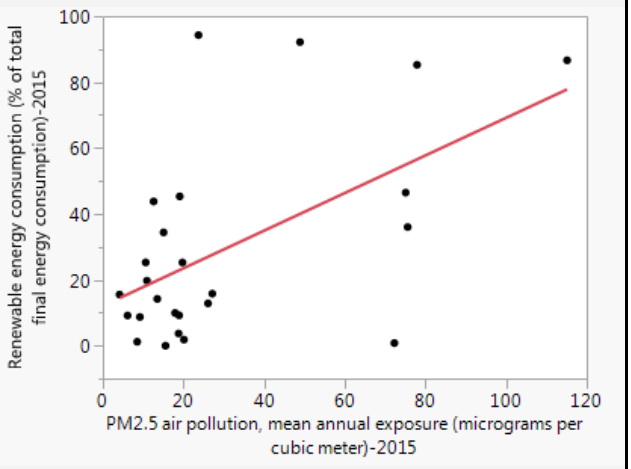
(For the purpose of these calculations, natural logs of the original values were considered)

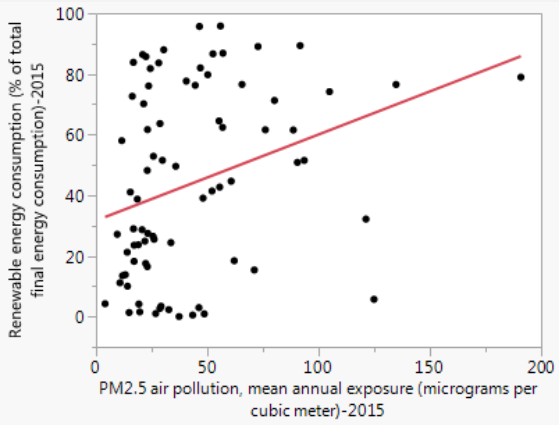
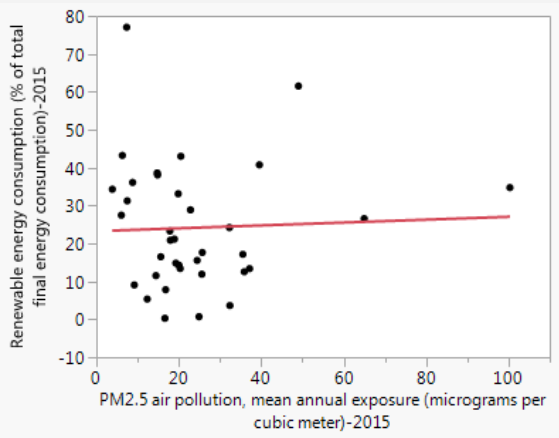
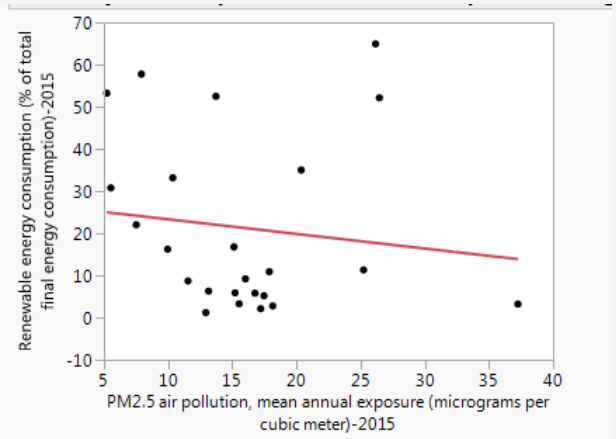
As the mean pollution levels and renewable energy consumption levels indicate, regions with higher pollution levels, are also the ones with relatively higher renewable energy consumption. For instance, South Asian countries have a mean pollution level of 62.41545 micrograms per cubic meter, and their renewable energy consumption is 45.22%. As against this Latin American and Caribbean countries have a mean pollution level of only 20.04294 micrograms per cubic meter, and their renewable energy consumption level is 19.81%.

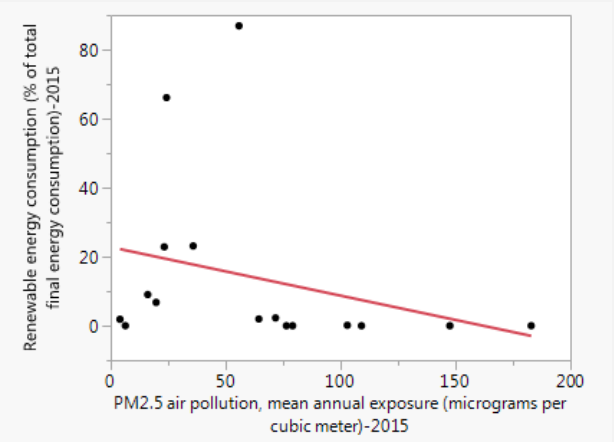
It is important to observe that merely high pollution level in itself does not imply high renewable energy consumption as there are other factors playing their role, for instance, government subsidies, research and development level, GDP (as research has already shown), etc. However, it is evident that a relatively higher level of pollution does lead to relatively higher renewable energy consumption levels. The huge difference in the mean consumption levels of different regions as shown in table(a) further hints towards the idea.

The type of governance prevalent in the country is one of the factors influencing renewable energy consumption. Nations that hold governments accountable to their citizens and have a high degree of pollution are the ones with a higher renewable energy consumption. As the figures below show, governments with accountability equivalent to that of a democracy or presidential republic have a higher correlation between pollution and renewable energy consumption. While parliamentary republics, monarchies, and communist states have a weak or negative correlation.

Table 2: Government Wise Renewable Energy Consumption Against Pollution

Government Type	R Square	R Adj	Mean of Responses	Chart
Democracy Equivalents	0.304115	0.273859	29.50529	

Presidential Republic	0.093138	0.081361	43.73567	
Parliamentary Republic	0.001748	-0.02761	24.16739	
Parliamentary Monarchy & Communist States	0.015289	-0.02947	21.27574	

Dictatorship & Absolute Monarchy	0.079389	0.013631	13.8174	

Note: Here, Democracy Equivalents include Democracy, Constitutional Federal Republic, Federal Parliamentary Republic, Parliamentary Democracy, and Presidential Democracy.

While this paper does not focus on exploring the reasons behind this, it could be because of reasons like nations with higher accountability are offering higher incentives to citizens to shift towards renewable energy consumption.

Conclusion and Implications

Pollution level present in the country and the type of government prevalent are two of the main factors driving renewable energy consumption across countries. Countries where pollution is a big problem and governments are accountable to their citizens are the ones with higher rate of renewable energy consumption. And nations with low pollution level or with relatively authoritarian governments are slow to adopt renewable energy.

Here, it is essential to note that this paper establishes correlations to show pollution as a factor of renewable energy. As a result, the conclusions drawn may need further statistical and intellectual confirmation through more research. While this research paper is limited to a descriptive study of the data, going ahead research can be done to explore the reasons behind the relationships established. Furthermore, there might be several other factors influencing the shift towards renewable energy that can be explored in future research.

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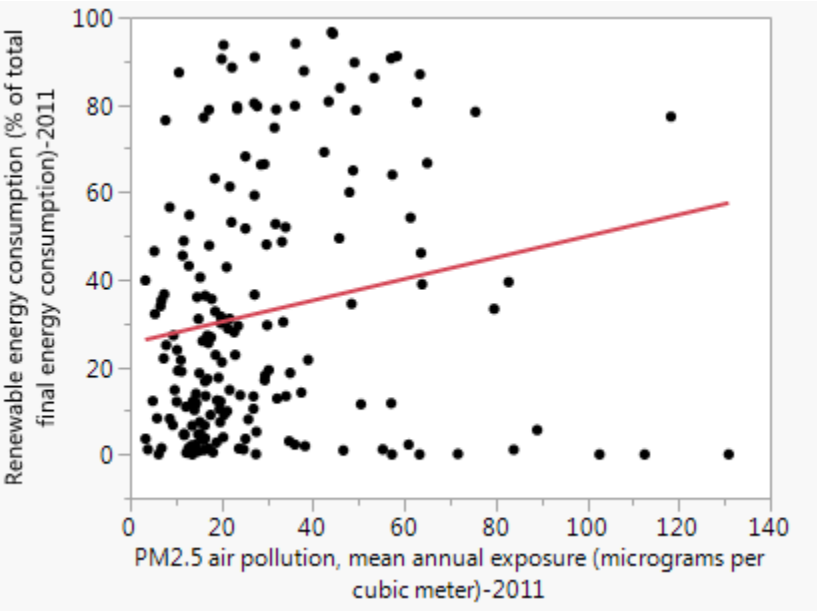
Appendix

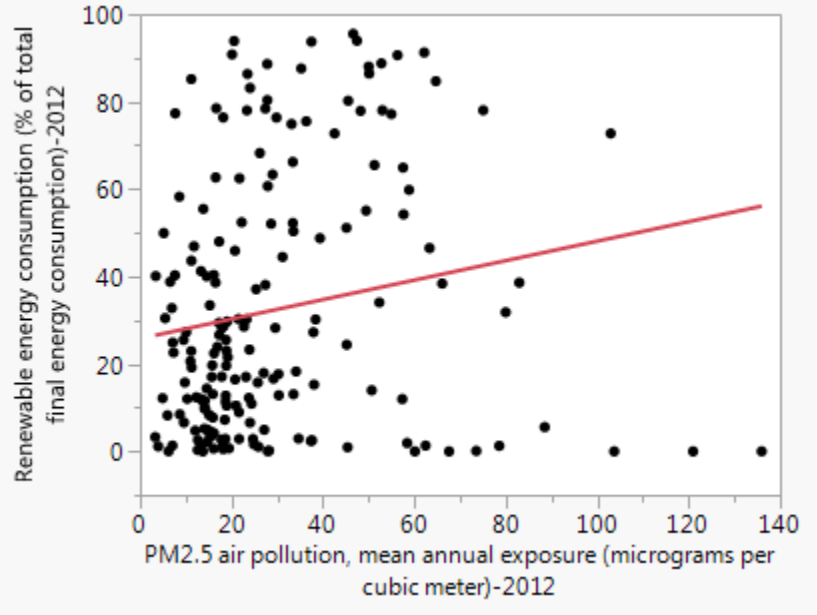
The following charts show the correlation between renewable energy consumption and pollution for 2011 to 2014. As can be seen, there is a positive correlation between air pollution levels and renewable energy consumption.

- 2011



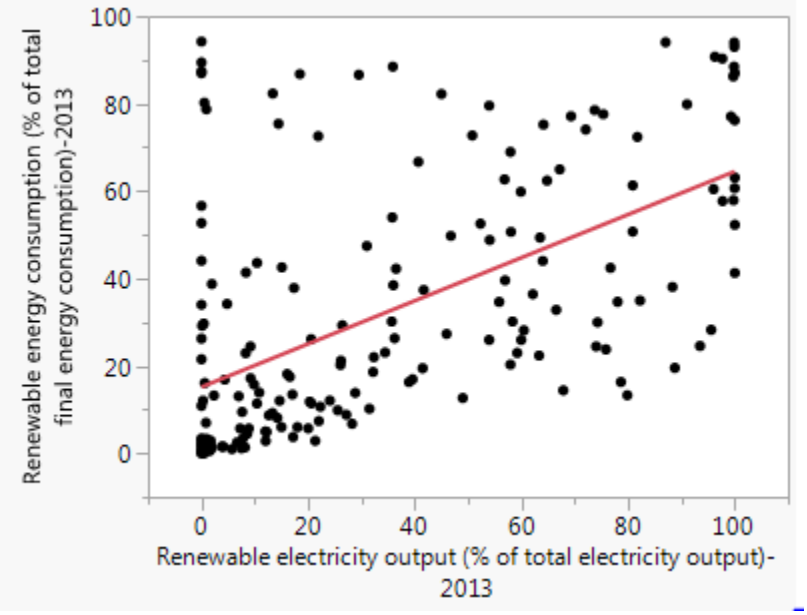
Summary of Fit	
RSquare	0.033711
RSquare Adj	0.028372
Root Mean Square Error	29.34171
Mean of Response	32.47981
Observations (or Sum Wgts)	183

- 2012



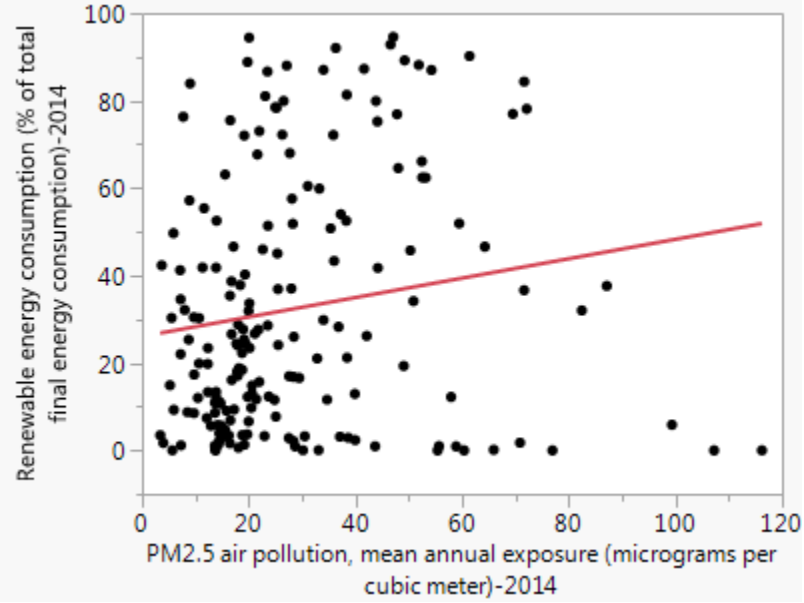
Summary of Fit	
RSquare	0.028712
RSquare Adj	0.023376
Root Mean Square Error	28.99419
Mean of Response	32.30455
Observations (or Sum Wgts)	184

- 2013



Summary of Fit	
RSquare	0.322969
RSquare Adj	0.319387
Root Mean Square Error	24.06271
Mean of Response	31.78301
Observations (or Sum Wgts)	191

- 2014



Summary of Fit	
RSquare	0.024615
RSquare Adj	0.019255
Root Mean Square Error	28.48455
Mean of Response	32.45305
Observations (or Sum Wgts)	184