An Examination of Carbon Emissions and Renewable Energies on Subjective Well-Being

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ABSTRACT

The heightened focus in the media on the adverse consequences of climate change, coupled with an increased public awareness of the economic costs associated with it, suggests that climate change could potentially influence the happiness levels of a nation. The World Health Organization (2023) has asserted that climate change represents the most significant health hazard confronting humanity. Additionally, according to the International Monetary Fund (n.d.), climate change poses a substantial threat to economic growth. The overall subjective well-being of a country is intricately linked to both its economic growth (income) and health. Consequently, climate change has the capacity to affect various facets of a nation's wealth, health, and overall well-being.

This study examines the impact of carbon emissions and renewable energy on subjective well-being (happiness). It analyzes data from 151 countries, covering the period from 2010 to 2018. The results show that in the combined data, carbon emissions do not impact subjective well-being (SWB) while renewable energy positively contributes to SWB. This analysis is broken down into several geographic regions for further study which shows regional differences for America, Africa, and Europe.

Key Words: Subjective Well-Being, Cantril Ladder, Carbon Emissions, Climate Change, Renewable Energy, Cross-Country

INTRODUCTION

An individual's level of subjective well-being, also referred to as happiness or life satisfaction, is influenced by a multitude of factors including economic and social conditions. In recent years, there has been increased recognition that environmental conditions also have an impact on happiness. Climate change has resulted in changes in temperature, precipitation, and the frequency and intensity of extreme weather events. These climate changes can disrupt economic growth and threaten access to basic needs such as clean water, food, and shelter. As the International Monetary Fund (n.d) states "Climate change presents a major threat to long-term growth and prosperity, and it has a direct impact on the economic wellbeing of all countries."

The World Health Organization (2023) estimates the direct costs of climate change on health is estimated to be between $2 billion to $4 billion per year by 2030. The impacts of climate change on subjective well-being are not uniform across different countries. Those in low-income countries may face disproportionate impacts given there are fewer resources to adapt or recover from climate-related events. Due to these inequities, climate change requires international cooperation and coordinated efforts to address it effectively. While it is easy to focus on the negative impact of climate change, there are also opportunities as economies transition to renewable energy sources. Energy-efficient technologies and sustainable practices may stimulate economic growth, create jobs, and generate new investment opportunities.

This study spans the years 2010-2018 for 151 countries. Two measures of climate change are considered: per person ton of carbon emissions and renewable energy as a percent of the total energy supply. According to the findings, carbon emissions have no effect on subjective well-being (SWB) for the consolidated data. However, renewable energy has a positive impact on SWB. The analysis is also segregated into various geographical regions, revealing distinct variations among America, Africa, and Europe.

LITERATURE REVIEW

Numerous scholarly publications have explored the determinants of subjective well-being in various nations. Due to the extensiveness of the research, the following provides a summary of the literature as it relates to SWB across countries and climate variables. In the literature, climate change is often referred to as environmental degradation or the deterioration of the environment.

One of the first studies in the area of cross-country SWB and environmental degradation comes from Welsch (2003, 2006). Using ten Organization for Economic Co-operation and Development (OECD) countries during the period of 1990-1997, Welsch studied the impact of nitrogen dioxide (NO_2), lead, and particles (air pollution) on subjective well-being. The author found a statistically significant negative relationship between SWB and nitrogen dioxide and lead concentrations. However, the relationship with particulate matter was found to be statistically insignificant in the regression analysis. Luechinger (2010) examined the effect of sulfur dioxide (SO_2) on life satisfaction in thirteen European countries. Over the 1979-1994 time period, the author finds that air pollution has a negative effect on life satisfaction. In their study conducted on European countries during 2002-2007, Ferreira et al. (2013) discovered a significant adverse influence of SO_2 concentrations on life satisfaction. This negative relationship existed in numerous models that controlled for income, education, age, health status, and other various socio-economic control variables. Majeed and Mumtaz (2017) studied happiness across 99 countries over the period 1980-2015. The authors find that carbon emissions and nitrous dioxide negatively impact happiness levels. These conclusions were robust to different model specifications, estimation methods, and control variables. The authors suggest that environmental policies to reduce harmful emissions are needed. More recently, Nicholas and Majeed (2021) studied how different forms of greenhouse gasses impacted happiness across 95 countries from 1990-2015. The authors used carbon dioxide (CO_2) emissions, nitrous oxide (NO_2), methane (CH_4), and total greenhouse gases. Greenhouse gases have a strong negative impact on happiness. Carbon emissions had the strongest negative impact and the authors conclude that countries having higher CO_2 emissions experienced lower levels of happiness. These authors recommend that policymakers should create policies that enable the transition from traditional energy sources to renewable energy. Due to the negative impact that the authors found, they also recommend that policymakers need to invest more in green technologies and green spaces. The general consensus in the research is that measures of environmental degradation have a negative impact on subjective well-being.

While there have been numerous research articles related to subjective well-being and climate change, most of the research uses air quality variables such as particulate matter or carbon emissions. Since a large portion of climate change is attributed to the use of fossil fuels, the need for renewable energy is considered crucial. Renewable energy is considered important, not only for meeting future energy needs, but also for mitigating climate change. As more individuals recognize the importance of climate change and the need for renewable energy, is renewable energy important in determining subjective well-being across countries? Some recent articles explore renewable energy as a potential determinant for measures of happiness across countries. The research that is available shows mixed results. Kumari, Kumar, and Sahu (2021) studied life satisfaction in the G20 countries from 2006-2019. Using renewable energy, GDP growth, carbon emissions, and non-renewable energy, the authors find that life satisfaction is positively related to renewable energy and GDP growth and negatively related to carbon emissions and non-renewable energy use. Ahmadiani, Ferreira, and Kessler (2022), in combination with socioeconomic factors, used several climate variables in their study of happiness across 96 countries, which was measured by life satisfaction, from 1995 to 2014. The authors used CO_2, particulate matter (PM_{10}) concentrations, amount of forest area, and renewable energy to gauge the impact that environmental issues may have on life satisfaction. The study found that life satisfaction was positively related to lower levels of CO_2 emissions, PM_{10} concentrations, and a larger percentage of forest areas. However, renewable energy (as a percent of total energy consumed) was not statistically significant as a determinant of life satisfaction. Omri, et.al. (2022) used renewable energy investment, measured by the renewable energy portion of global primary energy from the Energy Information Administration, and several measures of CO_2 in their study for 36 emerging countries over the period 2005 to 2014. The authors chose emerging countries due to their rapid economic growth and pollution concerns. The authors find investment in renewable energy has a positive influence on life satisfaction in emerging countries.

Though some recent studies have incorporated renewable energy as a potential factor influencing subjective well-being (SWB), there are few cross-country studies that disaggregate the overall findings into distinct geographic regions. This study uses two climate change metrics—carbon emissions per capita and the proportion of renewable energy in the total energy supply—across 151 countries from 2010 to 2018. It not only analyzes the impact of climate change measures on SWB across aggregate group of countries but also explores region-specific effects.

DATA

The foundation for the model used in this study was developed in the first World Happiness Report (WHR) released in 2012. This initial report laid the groundwork for a model to explain happiness or subjective well-being, as measured by the Cantril Ladder, across 139 countries. The estimated regression model used the Cantril Ladder to measure SWB and six important variables were found to impact SWB across the 139 countries: log GDP per capita, life expectancy, freedom to make life choices, corruption (business and government), having a social support system, and generosity. In addition to the WHR variables, recent research has shown that education may play a role in SWB (Ferreira et al. (2013), and Ahmadiani, et.al. (2021)). To ascertain the effects of climate on SWB, this study incorporates the key variables from WHR (2019) along with the education index, a component of the Human Development Indicator, the OECD reported measure of renewable energy as a percent of total energy supply, and carbon dioxide emissions from human activity (Andrews and Peters, 2021). The WHR (2019) data contains annual mean survey respondent (subjective) and mean objective data for 156 countries and is compiled from different sources including the Gallup World Poll (GWP), World Health Organization (WHO), and World Development Indicators (WDI). Complete and continuous annual data is not available for all sources for 2019-2021 time-period, therefore, the analysis is based on data from 2010-2018 time period. Table 1 (Appendix) provides a list of independent variables used in this study along with the literature cited for the expected relationship with Cantril Ladder.

In determining the choice of variables to estimate the effect of climate change on SWB, climate measures needed to be country-specific measures, have common public awareness as reported in the news media and other information sources, and in international climate change agreements. Two measures of climate change are considered: per person ton of carbon emissions and renewable energy as a percent of the total energy supply. Carbon Dioxide (CO2) emissions are reported as per person ton of carbon emission. Country measures for renewable energies were obtained from the OECD and include the production of energy from hydro, geothermal, solar, wind, and tide resources.

The U.S. estimates that the cost of carbon production is $51 per ton (Rennert and Kingdon, 2019). However, that estimate is far below that reported by Rennert, et al. (2022), estimating the societal cost of carbon emissions at $185 per ton. There is no direct comparison of the societal costs of carbon emissions and renewable energies. Comparing costs of electricity production from new sources indirectly measures the societal costs of production. Fossil fuel production costs range from $0.05-$0.15 per kilowatt hour as compared to average renewable energy costs of less than $0.10 per kilowatt hour (International Renewable Energy Agency, 2021). One would expect that the relative lower cost of renewable energy production would positively affect SWB, with carbon emission contributing negatively to SWB.

Descriptive statistics are provided in Table 2 (Appendix) and Table 3 (Appendix) for the 2010-2018 time period. Table 2 (Appendix) statistics are based on the full data set of 151 countries while Table 3 (Appendix) values are reported by region. The subdivision of world countries into the three regions considered herein is based on the United Nations Geoscheme (United Nations, n.d.): Europe, Americas, and Africa. Two other regions, Asia and Oceania, included in the United Nations Geoscheme are not considered in this analysis. Data on key variables is incomplete or not reported for Oceania. Asia is not reported since standard statistical correction techniques did not yield robust model results.

Worldwide, in Table 2 (Appendix), the mean carbon dioxide emissions is 4.4326-ton per person. Average regional carbon emissions over the nine-year reporting period are highest for Europe, however, beginning in 2014 carbon emissions are on the decline (see Figure 2 in Appendix). Carbon emissions for Africa have the lowest reported carbon emissions and are relatively stable over the 9-year reporting period. This is largely attributed to the industrial composition of the region and the availability of energy-producing infrastructure.

In contrast, Table 3 (Appendix), Africa reports the highest percentage of renewable energies. Renewable energies comprise 52.51 percent of total energy used. Since 2014, the region has shown a decline in renewable energy indicating a potential shift to carbon-based fuels (see Figure 1 in Appendix). Europe's mean renewable energy use is 17.50 percent for the 2010-2018 period. However, coinciding with the Paris Climate Agreement (UNFCCC, n.d.), adopted in 2015, energy from renewable resources increased by 6.47 percent between 2015 and 2018.

METHODOLOGY

The nature of the data, an unbalanced panel in combination with subjective and objective measures, is likely to exhibit serial correlation and heteroscedasticity. Apart from GDP, all the variables from the WHR are subjective measures. Survey responses based on perceptions in the current period are likely to be influenced by current and previous periods. The geographic proximity of countries shared cultural norms and common language, particularly among bordering nations, and international trade and public policies are likely to exhibit cross-country effects. Environmental policies governing the reduction and limitation of carbon emissions can be imposed upon trade partners and in the case of the European Union are regionally adopted. Infrastructure requirements for the production and delivery of renewable energies occur incrementally over time, with the compound effect of previous periods' infrastructure forming the foundation for additional energy infrastructure in the current period.

Controlling for any cross-country effects and time-dependent factors, model (1) is estimated using Seemingly Unrelated Regression (SUR), a generalization of feasible Generalized Least Squares (GLS). The assumptions of SUR are that the error terms are independent across time but with random within-period cross-equation heteroscedasticity (Zellner, 1962).

(1) $Y_{it} = \beta_0 + X\beta_{it} + Q\beta_{it} + Z\beta_{it} + V\beta_{it} + \varepsilon_{it}$

where Y = n x 1 Cantril Ladder measures
X = n x k matrix of variables from the WHR model
Q = nx1 vector of HDI education index
Z = n x 1 vector of total carbon dioxide emissions divided by midyear population
V = n x1 vector of percentage of renewable energies

SUR is applied to model (1) for all reporting countries. Region specific estimates of climate change and renewable energy on subjective well-being are estimated separately based on model (1) specification.

RESULTS

Table 4 (Appendix) reports the results of the model for all 151 countries. As expected, log GDP, life expectancy, freedom to make life choices, generosity, and social support have a positive, statistically significant impact on SWB across countries while corruption perception has a significant negative impact on SWB. The education index was not significant in this model. For the two climate variables, carbon emissions are not significant at the five percent level. This stands in contrast to previous studies by Majeed and Mumtaz (2017) and Nicholas and Majeed (2021).

There are several possible reasons as to why carbon emissions do not appear to impact SWB for the overall group of countries. First, the change in carbon emission ton per person from period to period is very small. This may indicate that carbon emissions have stabilized over time. Second, societal costs attributed to carbon emissions are not immediately observable, and costs are incremental over a long time period. In other words, the long-term impact of carbon emissions may not be factored into current period subjective well-being. Third, with the inclusion of renewable energy, which some studies do not include, it is possible that the positive impact of including renewable energy lessens the contribution of carbon emissions on SWB.

While carbon emissions are not significant, a ten-percentage point increase in renewable energy, on average, increases SWB by 0.049 points. In part, the positive contribution of renewable energy to SWB may be due to the fact the renewable energy production is observable: Solar panels, wind generators, and hydroelectric energy are all observable on the landscape. Even though the effect is small, it does indicate the potential value that individuals place on climate. As countries develop more renewable energy infrastructure, this signal, whether correct or not, shows that a country is actively combatting climate change. These results confirm the positive relationship found between life satisfaction and renewable energy by Kumari, Kumar, and Sahu (2021).

To further analyze these results, regional models are also estimated. Table 5 (Appendix) provides the results for the three regions; the Americas, Europe, and Africa based on the United Nations Geoscheme. For the Americas, log GDP, freedom to make life choices, generosity, and social support are all positive contributors (at the five percent level of significance) to SWB over this period. At the ten percent level of significance, education and carbon emissions negatively influence SWB. For the Americas, renewable energy does not influence SWB. For Europe, log GDP, life expectancy, freedom to make life choices, social support, and renewable energy are all positive and significant at the five percent level. Corruption has a negative impact on SWB. Education is positive and significant at the ten percent level. While renewable energy is a positive contributor to SWB in Europe, carbon emissions are not statistically significant. The results for Africa are markedly different. The R-square is lower compared to the other regions and there are fewer statistically significant contributors to SWB in this region. Freedom to make life choices and social support are the only two significant variables in the Africa model. It is interesting to note that log GDP and life expectancy are not significant in influencing SWB during this period for Africa and neither of the two climate variables are significant. These results show there are important differences across these regions for SWB.

Focusing on the climate change variables across the three regions, renewable energy has a significant impact in the Europe region but is not important in Americas or Africa regions. Carbon emissions have a negative impact at the ten percent level in the Americas but are not significant in Europe or Africa. From 2010 to 2018, renewable energy adoption in Europe increased from 13.15 percent to 20.19 percent. In contrast, renewable energy use in the Americas and Africa over the same time period decreased from 4.87 and 2.58 percentage points, respectively. The findings indicate regional differences in contributions to SWB. To the extent which climate contributes to SWB may be in part due differences in climate change awareness, climate policies, and existing energy infrastructure.

CONCLUSION

With the growing media focus on the adverse consequences of climate change, and consequently, heightened public awareness of the economic implications associated with it, one could argue that climate change could potentially influence a country's overall happiness. Utilizing data from 151 countries and spanning the years 2010 to 2018, this research adds to the literature by investigating the effects of carbon emissions and renewable energy on subjective well-being. The findings reveal that, in the aggregate data, carbon emissions do not have a significant impact on subjective well-being, while the presence of renewable energy contributes positively to SWB. Further regional analysis reveals variations in the relationship between these factors for America, Africa, and Europe.

The outcomes highlight notable variations in subjective well-being across the examined regions. When scrutinizing the climate change variables within these three regions, it becomes evident that renewable energy holds considerable significance in Europe, while its impact is negligible in the Americas and Africa. Conversely, carbon emissions exhibit a negative influence at the ten percent level in the Americas, yet lack significance in Europe or Africa. The identification of these regional distinctions stands as a key contribution of this study.

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APPENDIX

Table 1
Variable List

Independent Variable	Relationship with Cantril Ladder	Literature Source
Log Gross Domestic Product (GDP)	Positive	Helliwell (2003); Blanchflower and Oswald (2004)
Life Expectancy	Positive	Helliwell (2003); Evans and Soliman (2019)
Life Choices Freedom	Positive	Rae (2021)
Corruption Perception (Business and Government)	Negative	Ahmadiani, Ferreira and Kessler (2022); Li and An (2020)
Social Support	Positive	Helliwell (2003); Rae (2021)
Generosity	Positive	Rae (2021)
Education Index	Positive	Blanchflower and Oswald (2004); Ferrer-i-Carbonell (2005)
Carbon Dioxide (CO2) Emissions	Negative	Nicholas and Majeed (2021); Ahmadiani, Ferreira, and Kessler (2022)
Renewable Energy	Positive or No relationship	Ahmadiani, Ferreira, and Kessler (2022); Kumari, Kumar, and Sahu (2021)

Table 2
Descriptive Statistics - Worldwide (All Countries)

Variable	Mean	Standard Deviation	Minimum	Maximum	Observations
Cantril Ladder	5.4247	1.1579	2.6617	7.8581	1131
Freedom to Make Life Choices	0.7436	0.1406	0.3035	0.9851	1131
Corruption Perception	0.7461	0.1875	0.0473	0.9832	1119
Education Index	0.6573	0.1829	0.1800	0.9430	1156
Generosity	-0.0018	0.1633	-0.3363	0.6691	1124
Life Expectancy	63.4690	7.4795	32.30	76.80	1130
Social Support	0.8077	0.1211	0.2901	0.9873	1131
Log GDP	9.2177	1.1882	6.4659	11.4608	1125
Renewable Energy	27.9956	27.4467	0**	149.7318	985
Carbon Emissions	4.4326	4.8839	0*	35.00	1156

*Global Carbon Project (2020) reported zero carbon dioxide emissions for Burundi and Congo (Kinshasa)
**Renewable energy (OECD) as a percent of total energy use is reported as zero for Bahrain and Kuwait

Table 3
Descriptive Statistics -Regions

	Americas		
Variable	Mean	Standard Deviation	Observations
Cantril Ladder	6.1468	0.8266	196
Renewable Energy	34.7176	30.5717	199
Carbon Emissions	4.1492	5.9782	201
	Africa		
	Mean	Standard Deviation	Observations
Cantril Ladder	4.3108	0.6343	305
Renewable Energy	52.5108	30.7482	201
Carbon Emissions	1.0869	1.8623	314
	Europe		
	Mean	Standard Deviation	Observations
Cantril Ladder	6.1483	0.9563	323
Renewable Energy	17.5002	14.5480	326
Carbon Emissions	6.9592	3.3043	326
	Asia		
	Mean	Standard Deviation	Observations
Cantril Ladder	5.1853	0.9051	289
Renewable Energy	16.5972	19.9896	241
Carbon Emissions	4.8986	5.3602	297

Figure 1
Average Renewable Energy Supply as Percent of Energy Supply by Region: 2010-2018

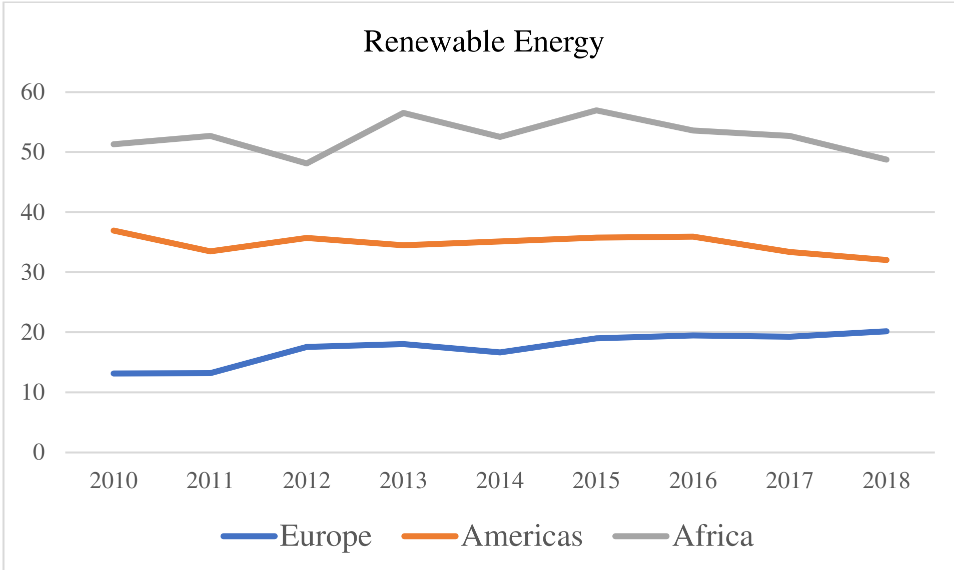

Figure 2
Average Carbon Dioxide Emissions Tons per Person by Region: 2010-2018

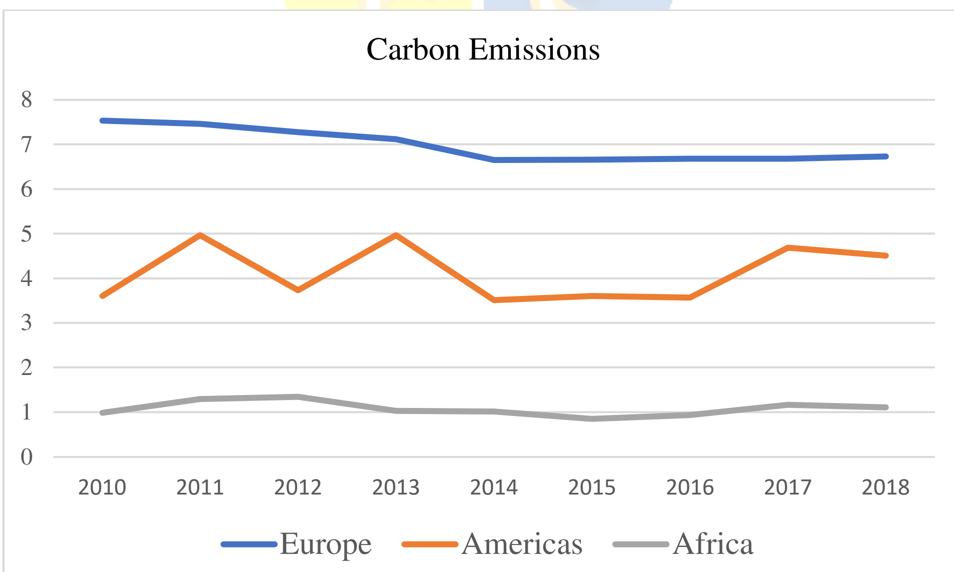

Table 4
Model Results: All Countries
Dependent Variable: Cantril Ladder

Variable	Coefficient	SE	Weighted Statistics	
Constant	-2.3356	0.6140	R-Square	0.4911
Log GDP	0.3639	0.0804*	F-Statistic	100.717*
Life Expectancy	0.0301	0.0097*	Durbin-Watson	1.6880
Freedom to Make Life Choices	1.1441	0.1830*		
Corruption	-0.5645	0.1778*		
Generosity	0.3265	0.1533*		
Social Support	1.8958	0.2596*		
Education Index	0.4768	0.4259		
Renewable Energy	0.0049	0.0017*		
Carbon Emissions	0.0139	0.0098		

*Significant at 0.05

Total panel observations: n = 949; Note: There are cases in the data where country level data for each consecutive year is not provided in the source data. This study only uses observations for which complete data was available.

Table 5
Model Results: Region
Dependent Variable: Cantril Ladder

	Americas		**Europe**		**Africa**	
Variable	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-2.700	1.1465	-1.5902	.9930	1.0846	1.3049
Log GDP	0.8924	0.1774*	0.2675	0.1276*	0.0904	0.1385
Life Expectancy	-0.0053	0.0140	0.0315	0.0194*	0.0219	0.0158
Freedom to Make Life Choices	1.4413	0.3013*	1.2248	0.2334*	0.8325	0.4078*
Corruption	-0.5799	0.3522	-1.1132	0.1940*	-0.2394	0.5457
Generosity	0.7115	0.3034*	0.1326	0.1721	0.9312	0.4768
Social Support	1.5914	0.5621*	1.7407	0.3758*	1.6088	0.4642*
Education Index	-1.774	0.9459**	1.2850	0.7593**	0.1358	0.8422
Renewable Energy	-0.0003	0.0023	0.0065	0.0026*	-0.0033	0.0034
Carbon Emissions	-0.0194	0.0117**	0.0038	0.0148	0.0149	0.0469
Weighted Statistics						
	R-Square	0.5172	R-Square	0.6271	R-Square	0.2423
	F-Statistic	22.0273*	F-Statistic	58.3055*	F-Statistic	6.5045*
	Durbin Watson	1.7702	Durbin Watson	1.8528	Durbin Watson	1.6556
	N	195	N	322	N	193

*Significant at 0.05
**Significant at 0.10

9%G