5-1-2022

What Dictates Carbon Dioxide Emissions Worldwide?

Bhowmik Sujey Soori

WHAT DICTATES CARBON DIXOIDE

EMISSIONS WORLDWIDE?

by

BHOWMIK SUJEY SOORI

Presented to the Faculty of the Honors College of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

HONORS BACHELOR OF SCIENCE IN ECONOMICS

THE UNIVERSITY OF TEXAS AT ARLINGTON

May 2022

ACKNOWLEDGMENTS

This work would not have been possible without the constant support of Dr. Christopher Candreva. I am especially indebted to him because of the constant advice he gave me during the process of writing the paper and patiently answering all my coding questions that I had during that period, some of which were admittedly a bit silly. Dr. Candreva was always supportive of me and pushed me to make this paper as good as possible. From cleaning the data to figuring out exactly what models to run, he was helpful and a valuable resource the entire step of the way.

April 22, 2022

ABSTRACT

WHAT DICTATES CARBON DIOXIDE

EMISSIONS WORLDWIDE?

Bhowmik Sujey Soori, B.S. Economics

The University of Texas at Arlington, 2022

Faculty Mentor: Christopher Candreva

The factors that lead to carbon dioxide emissions worldwide have been a popular topic for the last 30 years; however, a relatively underexplored topic is the relationship between carbon dioxide emissions and economic growth. This paper attempts to identify what type of relationship exists between carbon dioxide emissions, economic development, and energy consumption. Multiple econometric models, including Ordinary Least Squares (OLS), fixed effects, and a random effects model, were estimated for a panel data set of roughly 100 countries from 1960 through 2016. The results of the models show that there is no correlation between real GDP per capita and annual carbon dioxide emissions. These econometric models also show that the relationship between economic growth and carbon dioxide emissions is diversified due to the difference in regions and the diverse sources of energy that are used in each region.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure Page

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Climate change is one of the most important issues our world faces today. The reason it is such an important issue is because it is such a challenging issue to solve, and there are many different groups of people with varying opinions on how to go about combating climate change. In order to completely understand the policy implications of different ways to combat climate change, we would need to examine the relationship between economic growth, carbon emissions, and energy consumption. That being said, there already exists a good amount of literature that examines the relationship between economic growth and energy consumption, and then there is a separate literature looking at the relationship between economic growth and carbon emissions. The latter arguably is far more extensive than the former. However, there does not appear to be a lot of existing literature on how these two distinct areas of study might be interconnected and how they should be studied together so that we could combat the drawbacks of each type of study.

The primary research question of the paper is to identify what is driving carbon dioxide emissions worldwide. I believe this question is interesting because it is a very important question in the context of the current rate of rising temperature levels all around the world. Although this topic is very popular, and there have already been a lot of studies and papers about it, I think my paper is unique because it will use data that is more recent to identify exactly how population, income, and economic growth affect carbon dioxide emissions.

We plan on answering the question by gathering data that might possibly answer what drives the carbon dioxide levels all around the world. We will try to find data that would correspond to the well-known equation called the “kaya identity” (kaya and Yokoburi, 1997). Based on that equation, we will try to find data on population, per capita income, the amount of energy consumed per unit of Gross Domestic Product (GDP), and the amount of carbon dioxide emitted per unit of energy.

Because the datasets we are looking for would be panel data for countries all around the world at different points in time, we believe a random effects model might be used to answer my research question as it would allow me to control the time invariant component of the error term for the different countries. The econometric models in the paper show that there is a positive and statistically significant correlation between fossil fuel per capita and annual carbon dioxide emissions. This shows that it does not really matter how economically developed a country is or how much energy they are consuming and what truly dictates carbon dioxide emissions is the amount of fossil fuel the countries are using per capita.

CHAPTER 2

LITERATURE REVIEW

There are two major groups of empirical work that have been done in regard to this topic. The first group of the existing literature has tried to examine the relationship between the environment and the economic growth, and it has tested whether the Environmental Kuznets Curve (EKC) is valid or not. The EKC states that the environment is negatively impacted as income goes up; however, the environment will eventually get better as income increases in the long run (Grossman and Krueger, 1995). The primary research question of the paper was how the composition of economic activity and changes in the techniques of production affects the environment. The paper uses a cross-country sample of comparable measures of the pollution in various urban areas to explore the relationship between economic growth and air quality. The paper found that ambient levels of sulfur dioxide suspended in the air increase with per capita GDP at low levels of national income but decrease with per capita GDP at higher levels of income. The turning points for the different pollutants vary, but in most cases, they occur before a country reaches a per capita income of $8,000. For the third measure of air quality, namely the mass of suspended particles found in a given volume of air, the relationship between pollution and GDP is monotonically decreasing.

The issue with the aforementioned paper is that the data they used was very limited, and as such, their conclusions were very tentative. The paper also lacked what kinds of pollutants they had data on. Fortunately, over the years, we have started gathering a lot more data regarding emissions of carbon dioxide in different countries. So, analyzing novel and more full fletched data is a key area where my project differs from this article.

On the other hand, the other aspect of the empirical studies has been investigating the relationship between energy consumption and economic growth. One of the main papers that investigated this kind of relationship was written by Kraft and Kraft in 1978. The purpose of this paper was to determine the causal relationship between energy and Gross National Product (GNP). The paper states that there is a unidirectional relationship that runs from Gross National Product (GNP) to energy, and there is no causality from energy to GNP. Earlier versions of these studies, which were conducted in bivariate models, could have resulted in an omitted variable bias resulting in inconsistent estimates (Akarca and Long, 1980). My project will attempt to tie the relationship between energy consumption and economic growth into carbon dioxide emissions in an attempt to fix the omitted variable issues that may have been present in this article because of only looking at energy consumption and economic growth.

It has been argued by some researchers that these two strands of work must be studied together since the causal relationship between economic growth, energy consumption, and carbon emissions have important policy implications (Soytas and Sari, 2007). This paper investigates the effect of energy consumption and output on carbon emissions in the United States. Earlier research focused on testing the existence and/or shape of an environmental Kuznets curve without taking energy consumption into account. My project will have time series data from a large number of countries around the world. So, it will have a bigger pool of countries to analyze, and the data will be more robust.

Our paper is unique from any other empirical studies that have examined the relationships between economic growth, energy consumption, and carbon dioxide emissions and contributes to the literature in a multitude of ways. First, the data used is a lot more up to date than some of the more prominent literature in this area. Second, the paper will look at data from countries from all around the world as opposed to specific countries or specific regions that have not been done before. Third, the paper will divide countries based on their GDP and then analyze the causal relationships between energy consumption, Carbon dioxide emissions, and economic growth based on what stage of economic development said countries are in.

CHAPTER 3

METHODOLOGY

3.1 Potential Models

The purpose of this paper is to explore the relationship between real GDP per capita, energy consumption per GDP, and carbon dioxide emissions. I will also use fossil fuel per GDP as a control variable to account for what kind of energy source a country uses. Based on the data available, I would like to start by estimating a linear regression model based on Ordinary Least Squares (OLS).

$$Annual\ CO_2\ emissions = \beta_0 + \beta_1\ real\ gdp\ per\ capita + \beta_2\ energy\ consumption\ per\ GDP + \varepsilon$$

$$Annual\ CO_2\ emissions\ II = \beta_0 + \beta_1 real\ gdp\ per\ capita + \beta_2\ energy\ consumption\ per\ GDP + \beta_3 Fossil\ Fuel\ per\ GDP + \varepsilon$$

Given that the dataset we have is a panel dataset, we would also like to estimate the dataset using panel models to take into account the time invariant portion of the error term. As the data I have is panel data, OLS fails to exploit the benefits that are offered by a panel dataset. So, simply using an OLS model is probably not the best option. As a result, we will use the fixed effects model and the random effects model to see how those models account for the time invariant portion of the error term.

When looking at the data, we ran an Augmented Dickey-Fuller test to check for unit roots. We checked for unit roots because we did not want spurious relationships to appear in our regression models. The Augmented Dickey-Fuller test shows that there was evidence of unit roots within our dataset. These unit roots may cause a spurious relationship between our variables to appear statistically significant. This would throw off our results and mislead us about what is truly driving carbon emissions. Therefore, regressions in differences were used in addition to regression in levels.

3.1.1 Primary Hypothesis

We are trying to find a relationship between annual carbon dioxide emissions, Real GDP per capita, and energy consumption per GDP. Based on the summary statistics of the data available to me, we are expecting to find a positive relationship between real GDP per capita and Carbon dioxide emissions. Our primary hypothesis is that there will be a positive relationship between carbon dioxide emissions and real GDP per capita.

Therefore, the null hypothesis is that there is no significant correlation between real GDP per capita, energy consumption, and carbon dioxide emissions. So, the null hypothesis is that the coefficient for real GDP per capita and energy consumption will not be different from zero.

If the coefficient is statistically significant and higher than 0, then we can reject the null hypothesis and conclude the alternative hypothesis that there is a significant relationship between real GDP per capita, energy consumption, and annual carbon dioxide emissions.

$$H_0: \beta_1, \beta_2, \beta_3 = 0$$

$$H_1: \beta_1 \ or \ \beta_2 \ or \ \beta_3 \neq 0$$

3.2 Data Description

We use a dataset that was published by the Global Carbon Budget as part of the Global Carbon Project. The key variables in this analysis are Annual Carbon dioxide emissions, Real GDP per capita, and Energy consumption per GDP (Energy intensity). Annual Carbon dioxide emissions are measured in tonnes, GDP per capita is calculated in USD, and energy consumption per GDP (energy intensity) is measured in kilowatt hours per dollar. Energy intensity is a metric that reflects how energy-efficient an economy is. It is measured as the quantity of energy consumed to produce one unit of GDP. A lower energy intensity means it can generate more value added, with fewer energy inputs. Fossil fuel per capita is used to showcase what the energy composition of a country looks like. Fossil fuel per capita is calculated in KWh.

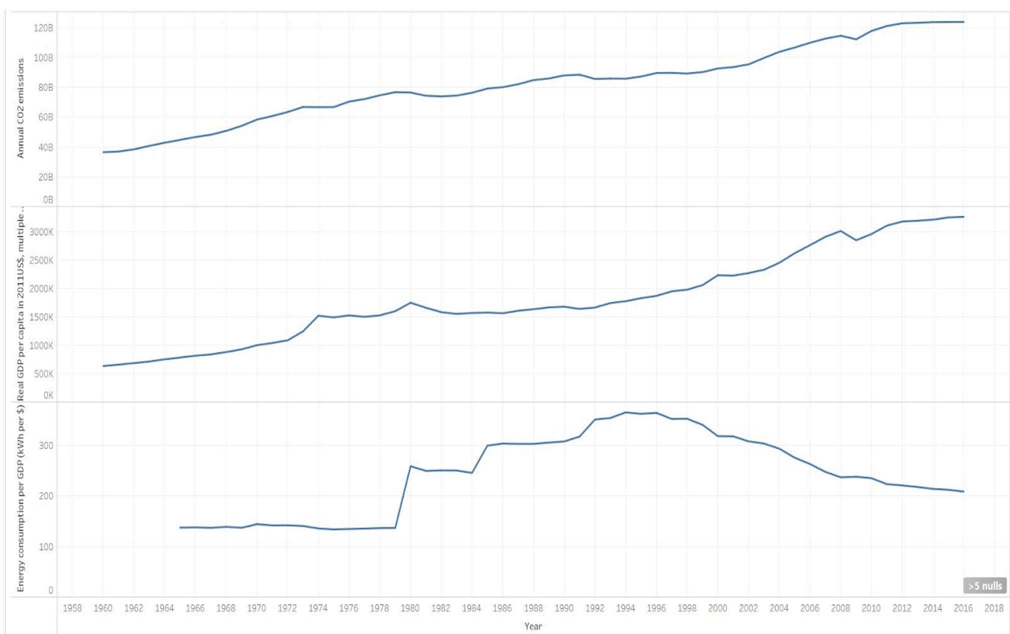

Figure 3.1: Graph of Annual CO2 Emissions, GDP Per Capita, and Energy Consumption per GDP

What these graphs show is that real GDP has increased substantially in this period all across the world; however, so has carbon dioxide emissions. So, for the purposes of this paper, my dependent variable will be annual carbon dioxide emissions, and my independent variables will be total population, real GDP per capita, and energy consumption per GDP.

The following table includes the summary statistics for the primary variables used in the models:

Table 3.1: Summary statistics of the dataset

Variable name	Mean	Standard Deviation	Min	Max
Real GDP per capita	10678.95	13986.83	134	220717
Energy consumption per GDP	1.850714	1.574786	0.05	13.493
Annual CO2 emissions	374762729	1883774995	3664	35244868107
Fossil fuel per capita	32860.41	35191.27	124.142	317582.5

CHAPTER 4

REGRESSION OUTPUTS AND ANALYSIS

Model 1: Effect of real GDP per capita, and energy consumption on annual carbon dioxide emissions in an OLS model (logs of variables are used in the model)

The OLS model shows that all of the independent variables in the form of the total population, real GDP per capita, and energy consumption are statistically significant. The model shows that a percent increase in real GDP per capita increases carbon dioxide emissions by 1.05%, and a percent increase in energy consumption per GDP raises annual carbon dioxide emissions by 0.85%.

This shows that the economic growth of a country and the amount of energy a country consumes has a statistically significant impact on the annual carbon dioxide emissions.

Model 2: Effect of real GDP per capita, energy consumption, and fossil fuel per capita on annual carbon dioxide emissions in an OLS model (logs of variables are used in the model)

The OLS model with the control variable—fossil fuel per capita, shows that only fossil fuel per capita is statistically significant. The model shows that a 1 percent increase in total population increases annual carbon dioxide emissions by 1.00%. It shows that a percent increase in fossil fuel per capita increases carbon dioxide emissions by 0.91%. This shows that the population of a country has a bigger impact on the carbon dioxide emissions of a country than the fossil fuel per capita of that country. The addition of the control variable also makes the energy consumption and real GDP statistically insignificant.

Model 3: Effect of real GDP per capita, energy consumption, and fossil fuel per capita on annual carbon dioxide emissions in a fixed effects model.

The fixed effects model shows that real GDP per capita, energy consumption per GDP, and fossil fuel per capita are all statistically significant.

The model shows that a percent increase in energy consumption per GDP increases carbon dioxide emissions by 0.51%. It also shows that a percent increase in fossil fuel per capita increases carbon dioxide emissions by 0.61%. This shows that the population of a country has a bigger impact on the carbon dioxide emissions of a country than the energy consumption and fossil fuel per capita of that country.

Model 4: Effect of real GDP per capita, energy consumption, and fossil fuel per capita on annual carbon dioxide emissions in a fixed effects model including a time trend variable.

In this model, we included a new variable named t in order to control for country fixed effects and see how GDP per capita, energy consumption, and fossil fuel per capita are truly connected to Annual carbon dioxide emissions. In order to do that, we made a variable for every country that started at increased at an increment of 1 starting in 1960 and continuing to 2016.

The fixed effects model with the time trend shows that real fossil fuel per capita and the time trend variables are statistically significant.

Model 5: Effect of real GDP per capita, energy consumption, and fossil fuel per capita on annual carbon dioxide emissions in a fixed effects model (using differenced data)

In this model, we first difference the data since the variables were not stationary. After differencing the data, it appears that GDP per capita and energy consumption per

GDP no longer appear to be statistically significant. Instead, the only statistically significant variable in this model is fossil fuel per capita.

Table 4.1: Regression Output Comparisons without the Differenced Data

Regression output comparisons

	Dependent variable:			
	lAnnualCO2emissions			
	OLS		*panel linear*	
	(1)	(2)	(3)	(4)
lRealGdpPerCapita	0.893^{***}	-1.269^{***}	0.643^{***}	-0.069
	(0.022)	(0.115)	(0.045)	(0.051)
lEnergyConsumptionPerGDp	0.905^{***}	-1.047^{***}	0.509^{***}	-0.003
	(0.032)	(0.126)	(0.048)	(0.049)
lFossilfuelspercapita		1.506^{***}	0.608^{***}	1.043^{***}
		(0.118)	(0.046)	(0.046)
t				0.011^{***}
				(0.0005)
Constant	8.534^{***}	16.012^{***}		
	(0.189)	(0.263)		
Observations	6,765	3,699	3,699	3,699
R^2	0.385	0.080	0.815	0.841

Notes: ***: significant at the 1% level. **: significant at the 5% level. The coefficients from Model 1 and Model 2 are from Ordinary Least Squares (OLS) regressions and the coefficients from Models 3 and 4 are from panel regressions. Standard errors are reported in parentheses below the coefficient estimates.

Table 4.2: Regression Output Comparisons with the Differenced Data

Regression output comparisons with differenced data

	Dependent variable:	
	DifferencedAnnualCO2Emissions	
	(1)	(2)
DifferencedGDPPerCapita	496.416	798.669**
	(472.182)	(313.424)
DifferencedEnergyConsumption	-718,581.500	1,430,963.000
	(4,129,935.000)	(1,918,578.000)
DifferencedFossilFuel	743.904***	
	(268.491)	
Observations	3,621	6,601
R^2	0.003	0.001

Notes: ***: significant at the 1% level. **: significant at the 5% level. The coefficients from Model 1 and Model 2 are from panel regressions. Standard errors are reported in parentheses below the coefficient estimates.

4.1 Outcome of the Hypothesis Test

Based on the econometric models used in this paper, we can reject the null hypothesis for real GDP per capita as all the models used in the paper estimated real GDP per capita to be a statistically significant variable.

When we used the OLS model without the fossil fuel variable, both GDP per capita and energy consumption were statistically significant. So, we would fail to reject the null hypothesis for those two variables in that instance. However, in model 2, fossil fuel per capita is the only statistically significant variable. So, that would allow us to reject the null hypothesis for energy consumption per GDP and GDP per capita. But, since there was stationarity in the data, the model with the most accurate results would be model 5 which has the differenced variables, and based on that model, the only statistically significant variable is fossil fuel per capita. So, we can reject the null hypothesis for energy consumption per GDP and GDP per capita.

CHAPTER 5

CONCLUSION

Our econometric models show that there is no correlation between real GDP per capita and annual carbon dioxide emissions. My literature review showcased that this was a topic that has been explored very heavily, and this result was a bit surprising. There was positive and statistically significant correlation between fossil fuel per capita and annual carbon dioxide emissions. This essentially goes to show that the makeup of a country's energy source affects the rate of annual carbon dioxide emissions a lot more than economic growth and energy consumption.

REFERENCES

Akarca, Ali T., and Thomas Veach Long. "On the Relationship Between Energy and GNP: A Reexamination." The Journal of Energy and Development, vol. 5, no. 2, International Research Center for Energy and Economic Development (ICEED), 1980, pp. 326–31, http://www.jstor.org/stable/24806899.

Gene M. Grossman, Alan B. Krueger, Economic Growth and the Environment, *The Quarterly Journal of Economics*, Volume 110, Issue 2, May 1995, Pages 353–377, https://doi.org/10.2307/2118443

Global Carbon Project. (2021). Supplemental data of Global Carbon Project 2021 (1.0) [Data set]. Global Carbon Project. https://doi.org/10.18160/gcp-2021.

Kaya, Yoichi; Yokoburi, Keiichi (1997). Environment, energy, and economy : strategies for sustainability. Tokyo [u.a.]: United Nations Univ. Press.

Kraft, John, and Arthur Kraft. "On the Relationship Between Energy and GNP." *The Journal of Energy and Development*, vol. 3, no. 2, International Research Center for Energy and Economic Development (ICEED), 1978, pages 401–03, http://www.jstor.org/stable/24806805.

Soytas, U., Sari, R., Ewing, B.T. Energy consumption, income, and carbon emissions in the United States. *Ecol. Econ,* 62 (3), 2007, pages 482–489. https://doi.org/10.1016/j. ecolecon.2006.07.009.

BIOGRAPHICAL INFORMATION

Bhowmik Sujey Soori hopes to do more research on developing countries since his area of interest is development economics. He plans on going to graduate school to get more research experience and aims on to earn a PhD one day.