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International Environmental Policy Agreements and their Effects on Reduction of Greenhouse Gases and Sustainable Growth

By
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Submitted in partial fulfillment of the requirements for
the Department of Economics

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Table of Contents

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Abstract

The emission of greenhouse gases is the primary source of environmental degradation leading to climate change. The gases released by one country create externalities that affect all other countries since the effects of pollution are not localized. Several international conferences have resulted in agreements aiming to hold countries accountable for reducing emissions. These conferences have been held with the expectation of limiting climate change to less than two degrees Celsius annual increase in global temperature. A visual depiction of this trend is featured in the Appendix. Before 2005, there were different, antagonistic schools of thought, resulting in failed consensus on how to handle these problems. The Kyoto Protocol, signed in 1997, is widely recognized as a failure in its inability to lead to major reduction of emission. Its failure can be partly contributed to this debate among countries. The European Union had advocated for sharp reduction of emission from all countries while China, India and Brazil claimed that reduction should be confined to the developed world (Brenton 2013). Their argument was that greenhouse gas emission was vital to their success in growing their GDP, as they are currently the largest developing economies, and do not want their growth to be restricted by these restraints.

This paper analyzes the measured change in emissions since 1990 across over 100 countries to determine how the GDP of a country in 1990 and the change of GDP since affect the change in emissions. The model controls for energy production and usage, and the changes of these numbers since 1990. All data are collected from The World Bank except oil production, which is obtained from the Organisation for Economic Cooperation and Development (OECD). This analysis aims to contribute to research on the progress of limiting greenhouse gas emission and conversion to renewable energy sources. It also draws attention to the relationship between

emissions and GDP as major emerging market economies are likely to be the largest source of future emissions. They can choose to develop using technologies that are more environmentally friendly than the technologies that have been used historically. As developing economies grow, there is expectation that emissions associated with this growth can be limited. Examining change in emissions since 1990 will allow us to see effects of the cultural change in awareness on environmental issues while also tracking the progress since the less influential Kyoto Protocol and the promising Copenhagen Accord.

CHAPTER ONE

Introduction

One of the most relevant issues in contemporary global politics is climate change and reducing greenhouse gas emission. The world's greatest powers have been under enormous pressure to find ways of reducing these emissions without detrimental effects on their domestic society. Greenhouse gases from human activities are the most significant driver of observed climate change. There are strong correlations between emissions and the wealth of a country. Developed countries have already grown their economies to a point of sustainability, so the goal of reduction of greenhouse gas emission is more attainable. This is not the case for developing countries, which they believe has placed them at disadvantage that already strong developed economies did not have to contend with when they were still growing. This means these countries believe reducing their levels of greenhouse gas emission will have detrimental effects on their growing economies. The question becomes can economies develop in environmentally sustainable ways or do these reduction goals cause a detrimental problem to developing economies. However, these countries are given the option of converting to sustainable practices sooner rather than waiting and taking up the cost after development. Since emissions have global consequences, what these countries decide will impact the rest of the world.

This paper studies the relationship between per capita GDP and greenhouse gas emissions. It attempts to add to the research on the effectiveness of international policy agreements, specifically the Kyoto Protocol and the Copenhagen Accord. Many scholars have recognized the Kyoto Protocol as a failure (Almer and Winkler, 2017). The agreement presented binding compliance of greenhouse gas reduction that was not meant. The goals of the

Copenhagen Accord were not binding but enough time has not passed to judge its effectiveness. The Accord, as a follow up of the Protocol, aimed to correct the mistakes they made in the previous agreement. While countries now exist in more of a consensus on the necessity of greenhouse gas abatement, it is up to the individual country to allocate their resources effectively. They have the choice of policy changes that have positive externalities in reduction of temperature growth. The goal accepted by environmental scientists is 2.5° Celsius increase of annual temperature. A graph of different possible scenarios of temperature change is presented in Figure 1.1 of the Appendix.

This paper looks at the per capita GDP of a country both in 1990 and the change since then to study the effect of GDP on both greenhouse gas emission in 1990 and its change since then. The year 1990 is a relevant in studying the reduction of climate change because of the Global Change Research Act of 1990, a United States Law mandating research into climate change and other related problems such as energy usage. It requires reports on the topic every four years. This study controls for renewable energy sources in 1990, fossil fuels, crude oil production and percent of GDP which comes from industry. It also controls for the percent change in all these numbers. It finds a statistically significant relationship between GDP and greenhouse gas emission. Both in terms of real numbers and percent changes. Further analysis shows the impact of these independent variables on the natural log of current levels of emissions. The final regression uses percent change of per capita GDP as the dependent variable with the purpose of seeing the correlation between renewable energy sources and per capita GDP growth. This final regression controls for urban population and urbanization, variables not included in any other model of this study.

CHAPTER TWO

Literature Review

Environmental policy has become a major issue in contemporary international politics as one country's reaction to this problem affects the rest of the world in terms of both environmental externalities and international relationships. One country's refusal to adapt has potential negative consequences on the rest of the world. As a result many international conferences have been held attempting to solve this problem and many scholars have conducted research on the effectiveness of these meetings and the broader topic of sustainable development. Scholars have been researching the environmental sustainability of long-term economic development since 1987 when the World Commission on Environment and Development outlined the definition of a sustainable society as: "one that meets the needs of the present without compensating the ability of future generations to meet their own needs." Researchers have been trying to solve the paradox of environmentally sustainable economic grow. The discussion has been analyzed across many fields including economics as high greenhouse gas emission is correlated with countries of wealth and high human welfare indexes.

William Nordhaus (2017) wrote on the necessity of cross-discipline analysis on climate change, specifically among the fields of sciences, economics and international policy. His argument for economics is that economic activity drives increased emissions, making reduction expensive. Meadows and others (2004) had outlined the connection between economic activity driving emission as well. In chapter 7 of their book they map out different scenarios of the future state of the world, material standard of living, human welfare and footprint based on how the world chooses to allocate sustainability through policy. All models indicate the correlation

between the current levels of growing human welfare index and human ecological footprint. Nordhaus (2017) develops a model explaining the necessity of cross-discipline analysis that he refers to. The model outlines that economic activity affects atmospheric concentrations, the climate and the hydrological cycle influencing human and natural systems, which ultimately contribute to the determination of climate policies. He calls this the Integrated Assessment Models of Climate change or IAMs. It means that economics activity affects the climate that affects human daily life that continues to affect the climate, as a cycle. What makes reduction so difficult is the commitment to the cost of reducing. Integrated assessment models developed by economists are vital in understanding what the results of climate policy and how they should be framed in order to be effective without being too expensive. The models in Meadows and other book mentioned above are examples of this interdisciplinary relationship. The models outline factors of economic growth such as industrial output effect factors of high material standard of living and human welfare. These indexes are high life expectancy, consumer goods per person, services per person and food per person. When population grows exponentially these standards become less sustainable.

Meadows and others (2006) outline three possible responses to climate change specifically discrediting the second in the models previously mentioned. The first response is the assumption that increased technology and the economic market system will take care of the problem. The second approach is to actively use technological and economic fixes, which they indicate only postpones the problem. An example of this is to limit the amount of pollution per mile of driving. As the world increases in development, the amount of miles driven will increase, delaying the problem. Nordhaus (2017) outlines another problem with the approaches to climate

change Meadows discredits, the economic costs of the destruction of recent natural disasters; Nordhaus specifically mentions hurricanes Harvey and Irma to illustrate how the impacts of weather events can be extremely large and devastating to the economy. Measures are urgently needed to compensate for environmental degradation. Bergh and Straaten (1994) conclude that environmental legislation cannot be discredited as a way to counteract the problem, developing functions of the modern environment-economy system. This further provides evidence for Meadows and other's third approach: acknowledge that the current human socio economic system is unsustainable and is heading for collapse, therefore, policy makers should aim to change this system.

Cooperation of the world's most influential powers in terms of addressing the problem of climate control has not fully been reached despite the recognition that reduction of greenhouse gases is necessary. Brenton (2013) analyzed the disputes of these countries separating them into three schools of thought in terms of how to handle climate change until around 2005 when they moved forward in cooperating. The 'Great Powers' refer to the EU, US, China, Japan, Russia, Brazil, India and Canada. Their debate resulted in the ineffectiveness of previous international agreements, including the Kyoto Protocol and the 1992 Rio convention. This is because although the goals set were mandatory, some countries that disagreed on the terms, choose to ignore the consequences. Specifically, China, India, and Brazil believed that action should be confined to the developed world, as their economies still needed space to grow and they believed that these restrictions would block their growth. However, if emissions are not reduced these nations are predicted to become the greatest greenhouse gas emitters in the upcoming century, replacing the

United States. Lack of compliance from these countries will also lead to an ineffectiveness of the policy agreements as the mandatory goals have no hard consequences.

The lack of compliance by countries who believe they are at a disadvantage in economic growth through forced reduction in emissions presents a problem in moving toward sustainable growth. Bergh and Staaten (1994) study historical and future models on economic development and how this relates to the environment. Through their study of past models they developed functions of the economy-environment systems showing the interconnectedness of these variables. This book was published over 20 years ago, but they draw attention to the lack of integration of ecological insights into economic theory, concluding that this allows countries to use traditional economic models as arguments for not researching sustainable development policies. Based on the research conducted for this paper, I would validate that this is still true today. There is still little consensus on how to effectively reduce the cost of emission reduction. Bergh and Straaten (1994) conclude that the modern economy is going to continue to reach environmental limits, being forced to adjust and develop into new systems.

McKibbin and Wilcoxen (2002) examine the key economic aspects of climate change and argue that economic theory provides vital guidance on climate change policy. The interconnectedness of the two fields are greater than they appear, similar to what Nordhaus argues. This paper is vital in explaining the necessity of my topic in relation to the field of economics. The study looks at Kyoto as a failure in terms of economic efficiency and shows that the global economy must be taken into account when these international agreements are made. The policy's approach was inefficient because it used the standard market-based policy instruments.. They point out that this would not work because climate change involves many

uncertainties and enormous distributional effects. This standard market-based analysis approach suggests a tradable permit system or an emission tax. The uncertainty comes from the science behind climate change that McKibbin and Wilcoxen (2002) clarify through “two indisputable facts.” The first fact is that certain gases in the atmosphere are transparent to ultraviolet light but absorb infrared radiation, the most relevant gas being carbon dioxide. The second fact is that the rapid increase of these greenhouse gases can be attributed to human activity. What is unknown to scientist is how much warming will result from a given increase in greenhouse gas concentrations and how long it will take for this warming to occur. It is also unknown how different regions will be affected by this change. These uncertainties are the reasons standard economic approaches will not be effective. The possible consequences of climate change, natural disasters, are also ones that affect the entire globe and their potential destruction could cause disruptions to the international economy as a whole. The reduction of greenhouse gas emission levels are expensive but so are the effects of climate change.

Frondel (2017) looks at individual level data to find how perceived risks on heat waves, storms and floods affect an individual’s perception of climate change. These natural disasters are a major possibility if climate change continues to progress at the current rate and presents the most immediate risk if action is not taken. This is less relevant to this research as it is at the individual level and provides no insight at the country level on international policy agreements or the economy. However, it provides context for the environmental movement culture and how it has grown in recent years. It also provides insight on whether the fear of destruction from natural disasters is a significant indicator in the belief of climate change. The fear of climate change provides an important indicator of support for domestic policy with the purpose of

decreasing emission, as it affects a government's willingness to devote resources to the cause. This paper looks at the German Household level data and finds that there is strong evidence of correlation between an individual risk perception and participation in movements to prevent climate change. Another factor that proved significant was whether or not the individual had personal experience with natural disasters. This could suggest that countries which are most affected by the change and have had to devote resources on cleaning up a destructive natural event are more likely to get involved with international policy agreements, as countries whose climate is more consistent may be less likely to want to reduce emissions for the sake of the international economy as they have never had to devote domestic resources to cleaning up its effects.

As of March 2017, the Kyoto Protocol was accepted as a failure in its influence for reduction of carbon dioxide emission. This agreement committed to reduce the emission of six greenhouse gases, but analysis by Almer and Winkler (2017) found little evidence proving emission reduction by the major emitters of the Annex B countries. The term Annex B refers to the signatory nations of the protocol. Almer and Winkler used a synthetic control model instead of traditional panel model finding this to be more effective when researching this type of topic. They found it controls for errors which come from using panel data to explain comparisons. This model is a statistical method that is used to evaluate the effect of a third party intervention in studies comparing groups, in this case countries. It involves the construction of a weighted combination of groups used as controls, to which the treatment group is compared, estimating the effect of the treatment. The two control groups they use are: (i) non-Annex B countries plus the US and (ii) US state-level data. The treatment is countries/regions without any binding GHG

emission targets under the Kyoto Protocol or countries/regions that would have had binding emission targets under the Kyoto Protocol but did not ratify it. The necessity of this type of analysis opposed to the traditional panel analysis was that countries cannot have both binding and nonbinding agreements.

Other studies also look at the empirical evidence on the effect of the Kyoto Protocol and find the binding agreements to be relatively ineffective. Iwata and Okada (2014) find a negatively significant effect on the commitment of reducing CO_2 and CH_4 and no significant reduction of N_2O. They used a stochastic version of the I=PAT model. I=PAT is an abbreviation for the variables going into the equation. The dependent variable representations are I for environmental impact that is a function of P for population, A for affluence, and T for technology. Population, affluence and technology are multiplied by each other to get impact. This paper has policy implications in terms of global warming as it shows a relationship of emission with population, affluence which is measured by real per capita gross domestic product, and technology measured in energy intensity and industrial structure. What this means is that GDP is connected with the rates of emission and gives perspective on what should be taken into account when creating the individual goals of a country's reduction (Iwata and Okada, 2014). This is also more evidence that international binding goals for reduction are not a motivating factor for domestic policy makers. What does motivate policy is the feeling of risk of global warming and awareness of the consequences. Binding goals of reduction are not enough of a motivator for countries to devote their resources to climate change efforts.

Furthering these results, Kim (2016) finds a negative effect of the Kyoto Protocol on international relations, specifically the trade flow. His finds this by using the gravity model and

the Quandt-Andrews test to study the relationship between trade and international agreements on climate change. Using this test, he find a structural break in 2003, one year after the Marrakesh Accord. Kim finds that these international greenhouse gas reduction agreements have a negative effect on the economy in terms of trade as trade is reduced when emissions are cut (Kim, 2016). This shows how these binding agreements have a potentially negative effect on international relationships by making countries more independent and making the international market smaller. This could also capture tension between countries that arose from these agreements as developing, industrial countries were not compliant in their participation believing they should have the right to continue growing their economy. Another possible explanation is the increased awareness in climate change has caused in increase of countries in using sustainable energy sources which are extracted domestically. Simultaneously decreasing the need for crude oil and other fossil fuel imports.

These developing industrial countries provide the most immediate risk of greenhouse gas emission. Lin (2016) studied the link between China's urbanization and carbon dioxide emission. The research question presented in this study was how to effectively reduce the cost of emission reduction. As mentioned previously through analysis of Brenton's (2013) study, China is one of the countries who was not compliant during international policy agreements believing they would be given a disadvantage in growing their economy. Lin finds a clear correlation between GDP growth, urbanization and carbon dioxide emission. With every 1% increase in the level of urbanization, GDP raises 0.671%. This increases carbon intensity by 0.274%. Lin found this through analysis of China's economic growth between 1985 and 2013. The connection between

urbanization and carbon dioxide emission provides further evidence that the fastest growing economies provide the biggest threat to sustainability.

The Copenhagen Accord was signed in 2009 as a result of the failure of the Kyoto Protocol. Cline (2012) researched the international economic challenges of this era, looking at the costs of this international strategy for abating greenhouse gas emission in response to the Copenhagen Accord. He looks at a path to limit the atmospheric concentrations of carbon dioxide to 450 parts per million (ppm) and limit the amount of warming to two degrees Celsius, which is the target by 2020. Cline also considers the state of the American political system and how this could affect the goal of Copenhagen. This chapter provides vital background analysis on the Copenhagen Accord without providing suggestions for reform or assistance developing a model for this research paper.

Further research provides analysis on the specific targets of the Copenhagen Accord. Dellink and others (2011) found the goals reached in this agreement to be not ambitious enough in limiting average global temperature increase to below two degrees Celsius. They found that to limit temperature increase to this extent it would cost around 0.3% of GDP from Annex B and non-Annex B countries and 0.5-0.6% of global real income to achieve, but do not observe the countries' individual goals to be at this level of commitment. This paper provides empirical evidence the target numbers in the Copenhagen Accord are too lenient to prompt real change, however, was done at a time where the effects could not yet be seen, so just provided a prediction. The failure of countries to reach their goal reduction numbers in the Kyoto Protocol may suggest that countries will not even reach these goals that Dellink and others prove are too lenient. They also provide analysis on the United Nations Framework Convention on Climate

Change's Cancun Agreement finding a similar unrealistic goal. Kypreos (2012) found that the Copenhagen Accord does not having binding commitments for developing countries, which means that the total warming target will probably not be met even if the Annex B countries reach their emission goals. This is because these developing countries are becoming the greatest risk factor for future emissions, not countries who have already developed their economy. This analysis provides further need for research on sustainable development.

Other research uses these international agreements to create a more realistic approach to reaching the goal of climate change reduction through lowering the rate of temperature change to the 2 degree Celsius target. Carraro and Massetti (2010) use historical data and focus on what can be done rather that what should be done. They are looking to create a more realistic model, opposed to the idealistic models used in developing the goals of the Copenhagen Accord. Their study uses the World Induced Technical Change Hybrid or WITCH model and provides evidence that a lower commitment on domestic abatement measures can be compensated by devoting about 50% of the Copenhagen financial provisions in 2020 to mitigation in Non-Annex I countries. This suggestion that the commitment for reduction could be lower if the resources of the conference were allocated in the direction of the consequences of climate change on the countries' failure to reduce emission.

This paper contributes to existing research through its economic analysis of climate change. Using emission as a function of GDP growth this paper shows the relationship between greenhouse gas emission and the economy. It aims to look at growth from this perspective to suggest policy implications that would allow developing countries to continue to develop their economy while reducing their greenhouse gas emission instead of allowing the two to grow as a

self reinforcing cycle. It also aims to contribute to the economic research in the field of environmental policy and how the two work together with a common goal, drawing attention to sustainable development as the overall goal as opposed to exclusive reduction.

CHAPTER THREE

3.1 Economic Model

To study the effect of GDP on change of greenhouse gas emission many factors that affect the emission rates must be controlled for. This includes fossil fuels, oil production and renewable resources. This paper uses the percentage change of emission and the current level of emissions as dependent variables for the main regressions. The percent change of all the independent variables must be controlled for as well. Using the 1990 values along with the percentage change allows the regression to track how growing economies affect emission. The goal of this model is to look at per capita GDP as a function of greenhouse gas emission and track the relationship. The controls allow for energy usage to be isolated from the relationship between emission and GDP.

The four main regression runs depict the difference when percent changes of the independent variables are included. Without the percent changes we see if the 1990 value of GDP and the controls have an influence on the percent change in emission. With the percent change we see if the change in these numbers has an effect on the change in the emission level. If GDP growth affected the ability to reduce emission we would see this in the second regression. If GDP in 1990 affected the countries ability to reduce emissions we would see this in either regression but in the second it is controlled by the change of GDP. Four more regressions are run that do not include the industry values. These four regressions are located in the Appendix because the results are not relevant to the study as the observations increase but other factors are lost.

Four more regressions are run capturing the natural log of the current level of greenhouse gas emission. Two of these regressions do not include industry controls and two do not include the percent changes of the independent variables. These models follow the format of the main regressions. The last model uses percent change in per capita GDP as the dependent variable with the attempt of finding a relationship between renewable energy sources and GDP growth. This model does not include industry controls but does include a new variable of percent urban population and percent change in this from 1990 to current value. This percent change captures urbanization.

3.2 Econometric Model

Dependent Variable

Most recent levels of emission-2016
Change in emission from 1990 to 2016

Natural log of most recent levels of emission-2016

Percent Change in per capita GDP
Independent Variables
Per capita GDP 1990
Change in per capita GDP from 1990 to 2016
Fossil Fuels in 1990
Change in Fossil Fuel from 1990 to 2014
Crude oil production 1990
Change in crude oil production from 1990 to 2016
Renewable energy generation in 1990
Change in renewable energy generation from 1990 to 2014
Percent of GDP from industry in 1990
Change of percent GDP from industry from 1990 to 2016
Percent urban population in 1990
Change of percent urban population between 1990 to 2016

Stochastic disturbance term

3.3 Data Description

This model uses 1990 as the baseline and measures the change in emission between then and now. This is a cross-country analysis, where data for all countries included in The World Bank database are incorporated. The study looks at major shifts from before international attention for climate change reduction through agreements such as the Kyoto Protocol (1997) and the Copenhagen Accord (2009). There are two main dependent variables that are run in the four main regressions. The first is the most recent data on greenhouse gas emission and the second is percent change since 1990. The percent change of total greenhouse gas emission is from 1990 to 2012, which is the most recent year that The World Bank had data for. The total greenhouse gas emissions is measured in kilotons of carbon dioxide equivalent but represents carbon dioxide, greenhouse gas, sulphur oxides, carbon monoxide, nitrogen oxides, and volatile organic compounds. The change in this number since 1990 will be the dependent variable, with the purpose of explaining its reduction or growth overall for each individual country.

Four supplementary regressions are run using the natural log of the most current levels of greenhouse gas emission as the dependent variable. This is coded as the natural log of the values from The World Bank used in the previous regressions. The most current levels are from 2012. A final regression is run using percent change in per capita GDP as the dependent variable. This variable is used as a main independent variable in all other regressions run and captures percent change between 1990 and 2016.

The main independent variable, per capita GDP, was collected by The World Bank as well and measured as a per capita unit in current US dollars. The most recent per capita GDP data comes from 2016 so the percent change represents the change from 1990 to 2016. The year

2014 is the most recent data available for renewable energy sources. The number refers to percent of total electricity generated by renewable energy sources. Percent change refers to the change in this percentage since 1990. The fossil fuel control variable is the percent of electricity generated from coal, natural gas and oil with the most recent data collected in 2014 as well. The percent of GDP which comes from industry variable was collected by The World Bank with the most current values coming from 2016. The World Bank has a dataset on percent of electricity which is generated from nuclear energy that was considered for this study. However, the data was disregarded as an independent variable because it was omitted from the regressions for multicollinearity.

The urban population independent variable was collected by The World Bank and captures the percent of the total population that lives in urban areas. This variable is only included in the regression that uses the percent change in per capita GDP as the dependent variable. The purpose of using urban population in this regression is as a proxy for emission. The Lin (2016) study links the urbanization of China with their increase in carbon dioxide emission as well as their exponential GDP growth. This study looks at the urban population in 1990 as the baseline and then the percent change between 1990 and the most recent available data, 2016, as a representation of urbanization.

The Organisation for Economic Co-operation and Development has datasets on crude oil production up through 2016, providing a relevant independent variable for this paper. The change in these numbers can should a cultural shift in the relevance of climate change, and the countries move to change their primary source of energy. Crude oil production is defined as the quantities of crude oil, natural gas and additives extracted from the ground. This indicator is measured in

thousand tons of oil equivalent. The current levels of extraction and the change since 1990 will be used as independent variables as well.

The data for this study that comes from The World Bank are collected from a subset of the available data called the World Development Indicators. They provide the most current and accurate global development data available, and including national (which is used in this paper), regional and global estimates. Regional estimators were dropped from the dataset as they enraptured that national data included, skewing the results. The the Organisation for Economic Co-operation and Development collected the crude oil production dataset from the International Energy Agency (IEA) World Energy Statistics.

Table 3.1: Descriptive Statistics

Variables	# of Observations	Mean	Min	Max	St. Deviation
Total Current Greenhouse Gas Emission	176	288,126.4	5.24	1.25e+07	1,116,415
% Change Greenhouse Gas Emission	174	820.58	-7901.84	85,620.36	6,795.21
Nature Log of Current Greenhouse Gas Emission	176	10.45	1.66	16.34	2.42
GDP 1990	179	6337.50	98.03	84,286.7	10,589.89
% Change GDP	166	83.34	-56.88	659.28	117.37
Renewable Resources 1990	196	31.41	0	100	35.93
% Change Renewable Resources	196	-.00593	-.7068	.6835	.1945
Fossil Fuels 1990	134	59.21	0	100	35.60

% Change Fossil Fuels	134	.0140	-.5486	.7068	.1966
Crude Oil Production 1990	136	61,022.59	0	3,044,520	310,792.1
% Change Crude Oil Production	136	153.69	-589.92	9,051.54	893.53
Urban Population 1990	212	52.1	5.42	100	25.04
% Change in Urban Population	211	23.17	-36.83	449.76	42.22
Industry 1990	127	30.92	4.99	83.25	13.30
% Change Industry	110	-6.80	-81.00	124.07	36.72

***Note:** The reported values are the means with the standard deviation in parentheses.

CHAPTER FOUR

Empirical Results

Table 4.1: Main Regressions

VARIABLES	(1) Total Greenhouse Gas Emission	(2) Total Greenhouse Gas Emission	(3) % Change Greenhouse Gas Emission	(4) % Change Greenhouse Gas Emission
GDP 1990	-19.86	-88.13***	-0.092	-0.73***
	(19.87)	(31.25)	(0.15)	(0.25)
% Change GDP		6,132.124**		64.488***
		(2,601.90)		(23.19)
Renewable	-6,566.07	-20,336.491	12.20	-89.92
Resources 1990	(13,436.41)	(13,135.19)	(99.12)	(95.89)
% Change		-737,128.21		717.24
Renewable		(2,978,694.67)		(21,835.84)
Resources				
Fossil Fuel 1990	-5,153.27	-17,410.87	24.81	-48.13
	(13,212.69)	(12,894.01)	(97.92)	(94.35)
% Change Fossil		-1,496,921.99		-2,532.43
Fuels		(2733874.28)		(20,035.21)
Crude Oil Production	9.02***	8.03***	0.019	0.009
1990	(2.50)	(2.36)	(0.018)	(0.017)
% Change Crude Oil		4,039.96***		30.77***
Production		(872.16)		(6.48)
Industry 1990	-3,880.96	-24,259.43	-2.14	-161.92
	(13,891.72)	(17,596.12)	(102.99)	(129.39)
% Change Industry		835.54		7.47
		(5,886.87)		(42.96)
Constant	1,022,534.50	2,782,593.91**	3.82	11,908.93
	(1,396,451.33)	(1,389,572.22)	(10,310.42)	(10,166.03)
Observations	82	75	80	73
R-squared	0.163	0.387	0.027	0.306

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The main regression results are presented above in Table 4.1. The first column displays the results with the current greenhouse gas emission levels as the dependent variable run with the 1990 levels and no percent change variables. The only independent variable here is the crude oil production of 1990 which is significant as the 1% level. The coefficient indicates that if the oil production of one country is 1 unit (thousand metric ton) higher, current greenhouse gas emission increases by 9.023 kilotons. GDP per capita from 1990 is insignificant in this regression. The R-squared is 0.163 indicating that 16.3% of current levels of greenhouse gas emission can be explained by included variables in this study.

The second regression depicts the results when percent changes are included. The R-squared increases to 0.387 meaning that with the percent changes, 38.7% of current levels of greenhouse gas emission can be explained by the independent variables in this study. Here both GDP per capita variables, 1990 value and percent change, are statistically significant. Per capita GDP in 1990 is significant at the 1% level. The coefficient indicates that if the per capita GDP of one country in 1990 increases by $US 1, current greenhouse gas emission decreases by 88.127 kilotons, this is holding percent change in per capita GDP constant. The percent change of per capita GDP is significant at the 5% level. The coefficient indicates that if this percent change increases by 1 percentage point then current greenhouse gas emission increases by 6,132.12 kilotons. The mean of greenhouse gas emission is 288,126 which means that this growth is about 2.13% of the average emission per country. Since this is holding 1990 levels of per capita GDP constant, this relationship reflects the impact economic growth has on greenhouse gas emissions both in real and percent change terms.

What this implies is that countries with a strong economy and countries with a growing country have different effects on emission. Countries which had a stronger economy in 1990 have lower rates of emission today and countries whose GDP has grown have high rates of emission. This growth is also greater than the reduction seen in the 1990 GDP coefficient. The controls which are statistically significant are crude oil production and percent change in oil production, both significant at the 1% level. The coefficient indicates that if the oil production of one country is 1 thousand metric ton, current greenhouse gas emission increases by 8.029 kilotons. When the percent change of oil production increases by 4,039.962 kiltons. This relationship further exemplifies the significance of crude oil production in explaining greenhouse gas emission.

The third and fourth regressions use percent change in greenhouse gas emission since 1990 as the dependent variable. The 3rd column shows the results without percent change, none of which are statistically significant. When the percent change are included both GDP variables become statistically significant along with the percent change in crude oil production, all at the 1% level. The R-squared also increased from 0.027 to 0.306 meaning that these percent changes explain 27.9% of variation between percent change in greenhouse gas emission. When GDP of 1990 increases by $US 1, percentage change in greenhouse gas decreases by 0.730 percentage points. When percent change of GDP increases by 1 percentage point, percent change in greenhouse gas emission increases by 64.488 percentage points. When percent change in oil production increases by 1 percentage point, greenhouse gas emission increases by 30.774 percentage points.

These results show that for countries with the same percent change in GDP, the one with higher GDP to in 1990 has had, on average, a smaller percent change in emissions. The relationship between GDP and greenhouse gas emission show that even with the active efforts of the world to decrease emission, these levels are still growing along with average per capita GDP. The results of the regression in column 4 show that countries that started with a higher per capita GDP have a smaller percent change of emission while countries who have high percent growth of per capita GDP are emitting more. This higher percent change of per capita GDP growth reflects a higher real change because baseline levels of GDP are controlled for. Figure 4.11, located in the Appendix shows that the countries which have the highest change in greenhouse gas emission are China, India and Brazil, which are the three countries who advocated for developing countries to not be held to the same standards in reducing emission. This graph also displays how countries which had a high GDP in 1990 have lower or average percent changes of emission.

When looked at in the cases of two countries who began started with simular per capita GDP we can see the relationship between GDP growth and increased emission, for example Mexico and Brazil. The two countries are both located in South America and began 1990 with per capita GDP that varied by only 15.3 US dollars. Brazil had a per capita GDP increase of 4.6% greater than Mexico, this reflects a greater real change as well since Brazil began with the higher per capita GDP. Both countries experienced growth of urbanization, increase in percent of energy coming from fossil fuels and decrease of percent of energy coming from renewable resources. The decrease for energy coming from renewable energy sources for Brazil was from 94.5% to 73.1% while for Mexico it was only 24% to 17%. The data indicates a decrease of

percent GDP coming from industry for Brazil but an increase for Mexico. However, the percent increase of greenhouse gas emissions for Brazil is about double the percent change for increase of greenhouse gas emissions for Mexico, reflecting a higher real increase as well. This is true regardless of Mexico's lower percent usage of renewable energy sources and growing industrial economy. This case study directly shows a link between fast growing economies and greenhouse gas emission. Brazil does have a higher percent growth of urbanization, which could be grounds for future research on sustainable growth.

The regressions show on Table 4.1 show the results when Industry variables are included. Although their inclusion raises R-squared, it dropped around 30 observations in each regression. Countries that have no data on the percent of GDP that comes from industry in 1990, but are included in the regressions in Table 4.1 are listed alphabetically as: Bahrain, Belgium, Canada, Cote d'Ivoire, Czech Republic, Gabon, Germany, Greece, Guatemala, Iceland, Indonesia, Israel, Jamaica, Japan, Kazakhstan, Libya, Luxembourg, Nicaragua, Oman, Paraguay, Peru, Poland, Portugal, Qatar, Slovak Republic, Spain, the United States, and Vietnam. These 28 countries are included in all regressions above but not in those regressions of Table 4.1. All other observations which were not included in the regressions in Table 4.1 were eliminated by other observations besides percent of GDP from industry in 1990.

The results of Table 4.4 are displayed in the Appendix of this paper. Since per capita GDP variables become insignificant and coefficient values decrease when the industry variables are not included, we see their inclusion are vital for the analysis of this paper. When they are not controlled for the correlation between the economy and emissions is lost, and this is the most

vital relationship of this study. Regression results are displayed in Table 4.4 and can be viewed in the Appendix.

Table 4.2: Regressions with the Natural Log of Emission

VARIABLES	(1) Natural log of Greenhouse Gas Emission	(2) Natural log of Greenhouse Gas Emission	(3) Natural log of Greenhouse Gas Emission	(4) Natural log of Greenhouse Gas Emission
GDP 1990	-0.000164	-0.0000172	-0.0000168	-0.0000373
	(0.000)	(0.000)	(0.000)	(0.000)
% Change GDP		-0.001		0.002
		(0.002)		(0.003)
Renewable Resources	-0.028***	-0.027***	-0.025*	-0.032**
1990	(0.010)	(0.010)	(0.013)	(0.014)
% Change Renewable		4.426*		0.960
Resources		(2.400)		(3.146)
Fossil Fuel 1990	-0.024**	-0.021**	-0.021	-0.025*
	(0.010)	(0.010)	(0.013)	(0.014)
% Change Fossil Fuels		4.367**		1.270
		(2.166)		(2.888)
Crude Oil Production	0.0106***	0.00201***	0.0104***	0.00949***
1990 (In millions)	(0.000)	(0.000)	(0.000)	(0.000)
% Change Crude Oil		0.001**		0.002**
Production		(0.001)		(0.001)
Industry 1990			-0.011	-0.030
			(0.013)	(0.019)
% Change Industry				-0.003
				(0.006)
Constant	13.86***	13.78***	14.03***	15.09***
	(0.97)	(0.98)	(1.35)	(1.47)
Observations	112	108	82	75
R-squared	0.281	0.347	0.235	0.310

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regressions depicted on Table 4.2 show the results when the dependent variable is the natural log of current levels of greenhouse gas emission. The purpose of this is to capture exponential growth of emission. Columns 1 and 2 display results without the inclusion of industry variables and columns 3 and 4 display the results with the inclusion of industry variables. Columns 1 and 3 do not include percent change independent variables while columns 2 and 4 do. This is all consistent with the previous models. Here we do not observe per capita GDP or growth of per capita GDP to be significant. Most independent variables that capture energy source and growth of these measure do prove to be significant in explaining the natural log of emission.

The percent of renewable energy in 1990 is significant in all four regressions. The coefficient in the first and second columns are significant at the 1% level remains relatively unchanged between one regression to the other. The first coefficient indicates that if we change the percent of energy coming from renewable resources in 1990 by 1%, the level of greenhouse gas emission emission decreases by 2.8%. When percent independent variables are included in the regression the level of greenhouse gas emission emission decreases by 2.7%. The inclusion of independent variables indicated industry does not change the coefficient significantly but does make the variable less significant. Column 3 shows that when percent independent variables are included in the regression the level of greenhouse gas emission emission decreases by 2.5% and this is significant at the 10% level. Column 4 shows that when percent independent variables are included in the regression the level of greenhouse gas emission emission decreases by 3.2%, significant at the 5% level. Percent change in renewable resources between 1990 and the most recent values is only significant in column 4, when industry variables are not included, and this is

significant at the 10% level. This coefficient indicates that when we increase percent change of energy coming from renewable resources by 1%, emission of greenhouse gases increases by 442.6%. Since this coefficient decreases and becomes insignificant when controlled for industry variables, this result could be capturing industrial change.

The percent of energy that comes from fossil fuels has a similar correlation to the natural log of emissions as the percent of energy that comes from renewable resources. Here we see coefficients being significant in every column except the third column. Column 1 shows that if we change the percent of energy coming from fossil fuels by 1%, greenhouse gas emission decreases by 2.4%, significant at the 5% level. Column 2 shows that if we change the percent of energy coming from fossil fuels by 1%, greenhouse gas emission decreases by 2.1%, significant at the 5% level. Column 4 shows that if we change the percent of energy coming from fossil fuels by 1%, greenhouse gas emission decreases by 2.5%, significant at the 10% level. Percent change in the percent of energy which comes from fossil fuels is only significant in the second column, where industry variables are not included, similar to that of renewable resources. This is significant at the 5% level. This shows that if we change the percent change of fossil fuels between 1990 and current value by 1%, greenhouse gas emission increases by 436.7%.

The values of crude oil production for 1990 had to be converted to million tons for this regression because the coefficients were too small to interpret. The values are significant at the 1% level in every regression. In column 1, if crude oil production increased by 1 million metric tons, current greenhouse emissions increases by 1.06%. In column 2, if crude oil production increased by 1 million metric tons, current greenhouse emissions increases by 0.201%. In column 3, if crude oil production increased by 1 million metric tons, current greenhouse

emissions increases by 1.04%. In column 4, if crude oil production increased by 1 million metric tons, current greenhouse emissions increases by 0.949%. We also observe that 1% change of crude oil production between 1990 and current levels, increases current levels of greenhouse emission by .1% without industry variables (column 2) and .2% with industry variables (column 4). These coefficients indicate insignificant variance from when industry variables are included and they are not, showing the effect of oil on greenhouse gas emission to be independent from industry growth.

These regressions help explain the independent variables' correlation with current levels of greenhouse gas emission in terms of percentages. This regression also helps with explaining which independent variables are correlated with industry growth. The coefficient of percent changes in energy that comes from renewable resources and the percent change of energy that comes from fossil fuels becomes smaller and insignificant when industry variables are included. This means that part of this coefficient was capturing industry growth.

The following regression, Table 5, aim to capture how conversions to more sustainable energy sources affects the growth of the economy. Urbanization is used in this regression to as a proxy for emission as the Lin (2016) empirically links urbanization to carbon dioxide emission. GDP of 1990 is use as a control to capture the influence these independent energy variables have on growth of GDP controlling for resources that can be allocated toward sustainability. The purpose of this regression is to add to the research on sustainable development.

Table 4.3: GDP as Dependent Variable

VARIABLES	(1) Percent Change GDP
GDP 1990	0.01***
	(0.001)
Urban Population 1990	1.41***
	(0.49)
% Change Urban Population	0.294 (0.365)
Crude Oil Production 1990	-0.000 (0.000)
% Change Crude Oil Production	-0.032 (0.03)
Renewable Resources 1990	1.19** (0.59)
% Change Renewable Resources	-74.12 (138.80)
Fossil Fuel 1990	1.29**
	(0.57)
% Change Fossil Fuels	-73.85
	(126.29)
Constant	-168.32***
	(63.91)
Observations	115
R-squared	0.670

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The most significant coefficient results from this regression are that of percent of energy that comes from renewable resources in 1990. The coefficient indicates that with a one percentage point increase of energy coming from renewable resources, percent change of per capita GDP increases by 1.19 percentage points, significant at the 5% level. This result provides

evidence that conversion to sustainable energy sources does not have a negative effect on growth of per capita GDP. The increase usage of sustainable energy sources has a possible correlated with GDP growth, even when controlling for initial level of per capita GDP.

The coefficients for urban population in 1990 and percent of energy coming from fossil fuels are both significant at the 5% level. With a one percentage point increase of population in urban areas, percent change of per capita GDP increases by 1.41 percentage points. With a one percentage point increase of energy coming from fossil fuels, percent change of per capita GDP increases by 1.29 percentage points. Both these coefficients are consistent with the general consensus of economic growth, but these are controlled for in the renewable resource coefficient and do not take away from its significance.

CHAPTER FIVE

Conclusion

This paper shows that per capita GDP levels in 1990 have a negative relationship with greenhouse gas emission while per capita GDP percent change since 1990 has a positive correlation. What this means is that for two countries with the same per capita GDP in 1990, the one with the larger percent change has a larger total emissions. It also means that for two countries with the same percent change of per capita GDP, the one with the higher level of per capita GDP in 1990 has lower real emission rates. Percent change in per capita GDP, holding per capita GDP of 1990 constant, shows that countries whose per capita GDP has grown with greater percentage change have higher percentage growth of emission. This indicates that these growing economies are already responsible for the biggest increase in the greenhouse gas emission, while other economies are able to at worst remain relatively stable in their emission levels. In Figure 4.1, we can see that China, India and Brazil, the countries that did not cooperate in the Kyoto Protocol, have greatly increased their percent change in emissions, while having lower per capita GDP in 1990. We also observe this relationship in the case study comparing the data on Brazil to Mexico.

This analysis does not answer the question of what countries can do in terms of emission reduction, but it does show which countries are responsible for increasing global emission levels and provide evidence of crude oil production as a significant predictor of this. This could be due to these countries reluctancy to see the burden of climate change as a domestic problem. These developing countries were minimal in the greenhouse gas emission until now, so they could feel less of a urgency in helping to solve the problems This also could be due to unintended

consequences of a growing economy, such as urbanization. As per capita GDP per capita increases more people in the community can afford to engage in activities that have negative consequences to the economic impact on climate change, such as driving a car everyday. The case study comparing Mexico and Brazil provides evidence that this could be explored further, especially in the subfield of sustainable growth. This study further provides evidence that conversion to renewable energy sources does not negatively impact per capita GDP growth, providing evidence that countries with higher baseline levels of renewable energy sources have a positive correlation with economic growth. This relationship provides background for further research on sustainable growth as it provides evidence for fast growing economies as the biggest upcoming greenhouse gas offenders.

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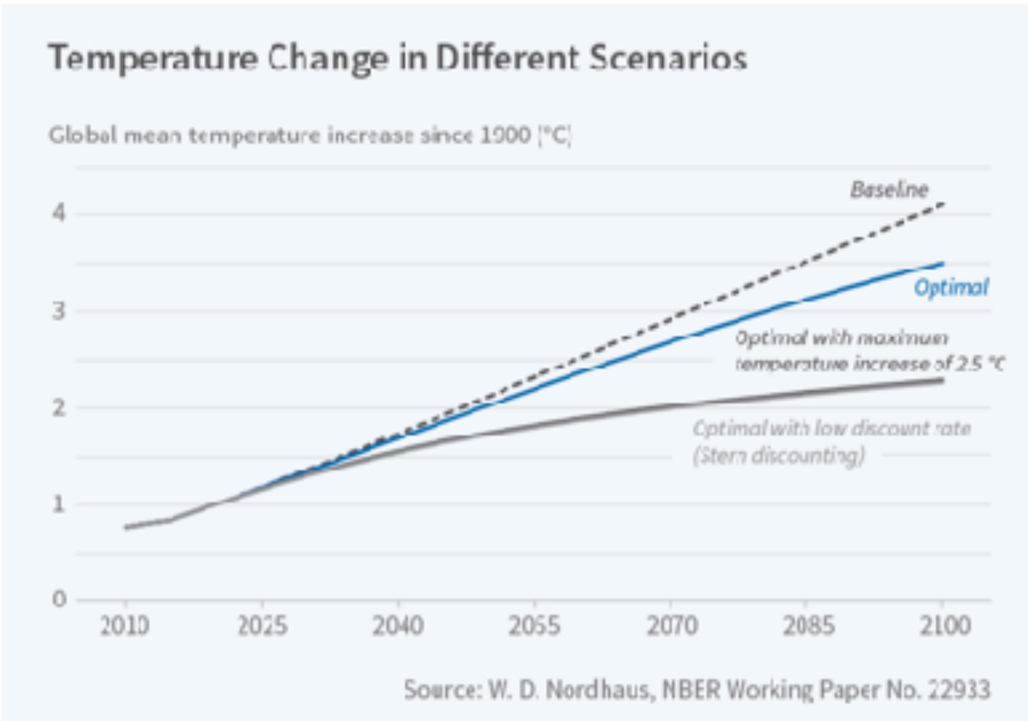
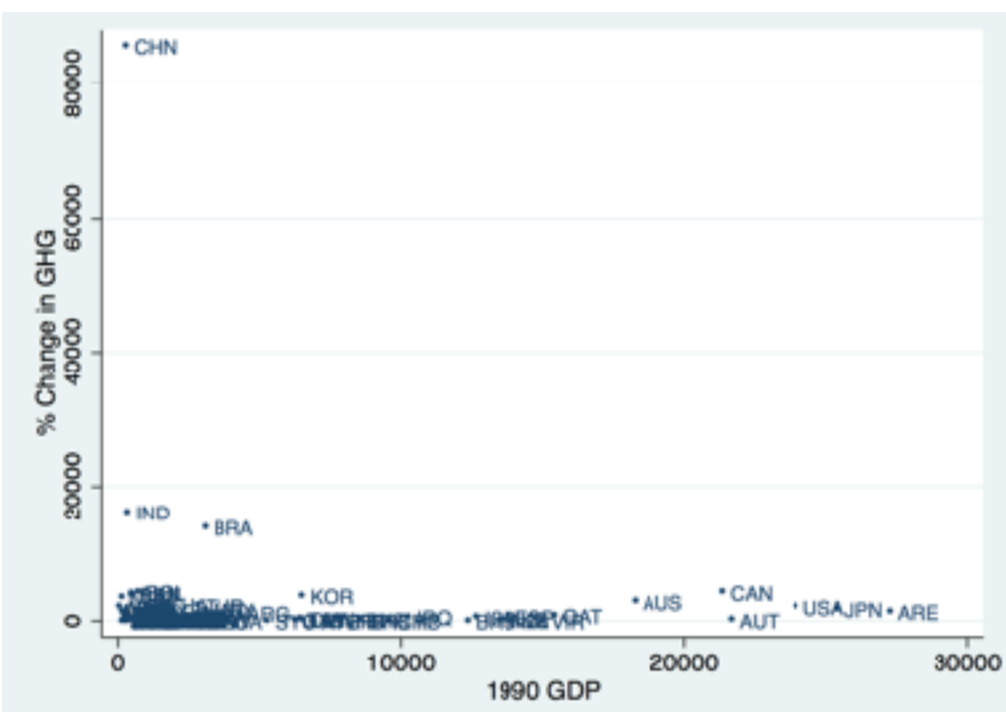
Appendix

Figure 1.1:



*Explains the purpose of the 2.5°C goals of the international policy agreements

Figure 4.1



*This scatter plot shows only countries which have positive change in greenhouse gas emission.

Table 4.4: Regressions without Industry Variables

VARIABLES	(1) Total Greenhouse Gas Emission	(2) Total Greenhouse Gas Emission	(3) % Change Greenhouse Gas Emission	(4) % Change Greenhouse Gas Emission
GDP 1990	-8.10	-43.02*	-0.072	-0.304*
	(13.95)	(22.31)	(0.10)	(0.17)
% Change GDP		2,063.54		14.66
		(1,484.85)		(11.30)
Renewable Resources 1990	-5,901.41	-9,513.59	14.43	-15.73
	(9,225.0)	(9,201.53)	(65.90)	(66.54)
% Change Renewable Resources		2,277,805.95		13,418.88
		(2,164,744.71)		(15,652.72)
Fossil Fuel 1990	-5,414.62	-9,380.86	20.44	-8.27
	(9,121.33)	(9,053.61)	(65.37)	(65.54)
% Change Fossil Fuels		1,673,293.99		10,741.66
		(1,953,342.81)		(14,127.75)
Crude Oil Production 1990	10.92***	9.42***	0.016	0.003
	(1.77)	(1.82)	(0.013)	(0.013)
% Change Crude Oil Production		2,161.64***		14.96***
		(560.57)		(4.06)
Constant	772,069.22	1,118,090.14	-308.39	2,196.68
	(906,006.56)	(884,014.53)	(6,475.91)	(6,392.77)
Observations	112	108	110	106
R-squared	0.269	0.379	0.023	0.151

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1