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THE EFFECT OF THE INVESTMENT TAX CREDIT POLICY ON RENEWABLE ENERGY RESOURCES IN THE UNITED STATES RELATIVE TO EUROPE

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by

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ABSTRACT

This paper aims to explore the effect of the Investment Tax Credit policy on the production and usage of renewable energy resources in the United States and whether the implementation of this policy in the US helped close the gap with European Countries. It focuses largely on the economic theory of incentives, cost/benefit analyses, and the theory of externalities. To analyze this, data was collected from the World Bank and the Quality of Government Dataset and the effectiveness of this policy was measured using four outcome variables: Renewable Energy Consumption, Fossil Fuel Consumption, Renewable Electricity Output, and Greenhouse Gas Emissions. A difference in difference model is used to measure the impact of the policy before and after it was implemented in 2006. My initial findings found that the implementation of this policy did little to nothing in closing the gap between the US and European Countries in the production and usage of renewable energy resources, but there may have been an impact in the US alone.

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TABLE OF CONTENTS

INTRODUCTION

As climate change continues to damage the planet, from severe changes in weather patterns to the warming of our oceans, the production and usage of renewables is becoming increasingly important to help mitigate these detrimental effects. Climate change not only harms our environment, health, and ecosystems, but also the damages caused by climate change will severely impact global economies and businesses due to disruptions in trade and supply chains throughout the world. We have already begun to see the economic effects of climate change in the United States in recent years due to extreme weather patterns like hurricanes and wildfires, and those alone have cost approximately $415 billion in the last three years (Cho, et al, 2019). With the rise of new technology and a collective focus in incentivizing renewable energy resources through tax credit policies like the Investment Tax Credit Policy, the effects and economic costs of climate change could be greatly reduced.

The United States has made progress in increasing the amount of energy produced from renewable energy resources from the years 1990 to 2015. However, in Europe, one of the most important rivals and partners to the US, strides towards renewable energy resources have grown significantly more. In the US, from 1990 to 2015, renewable energy output increased from approximately 2.5% to 8% of total energy consumption. In Europe, countries' renewable energy output increased from 14% to 25% of total energy consumption (World Bank, 2020). While the percentage of renewable energy consumption in the US grew 320% and European countries only grew 179%, the percentage in 2015 in the US is still far below the percentage in Europe in 1990. It is certainly encouraging to see the United States rapidly increasing in their renewable energy output through the years, but there is still a significant gap between the economically and developmentally comparable countries in Europe and what they have achieved in terms of renewables.

In this paper, I examine the Investment Tax Credit Policy with a difference in difference model, to see if tax incentives encourage the production and usage of renewables in the United States, and whether the implementation of this policy helped close the gap between the US and Europe in their usage of renewables. The Investment Tax Credit Policy is an incentive policy for the development and deployment of renewable energy technologies. It reduces federal income taxes for qualified tax-paying owners based on capital investment in renewable energy projects (measured in dollars) and is earned when the equipment is placed into service (Goodward et al, 2018). The effects of climate change have huge financial impacts on food production, human health, and the country's economy. Tax incentives could be an extremely effective way of encouraging the implementation of renewable energy resources in the US to help mitigate these detrimental effects.

To analyze this, I gather panel data from World Development Indicators, the Quality of Government dataset, and data on renewable energy output from the years 1990-2015 for the United States and various European countries. This dataset allows me to examine trends in the production and usage of renewable energy resources before and after the Investment Tax Credit Policy was implemented in 2006 in the US.

I find little to no evidence that the Investment Tax Credit policy helped close the gap for renewable energy production and usage in the US versus Europe, however there may have been an impact in the US alone. This contradicts my initial hypothesis that the Investment Tax Credit Policy would have an impact in the United States relative to Europe, perhaps due to global events such as the 2008 recession which increased prices of oil worldwide, or general global advancements in renewable energy technology.

BACKGROUND

The Investment Tax Credit Policy, also known as the Solar Investment Tax Credit Policy is one of the most prominent tax credit policies for renewable energy in the United States. The Investment Tax Credit Policy is one of the most important federal policy mechanisms to support the growth of solar energy in the United States, and since it was enacted in 2006, the US solar industry has grown by more than 10,000% creating hundreds of thousands of jobs and investing billions of dollars in the U.S. economy in the process (SEIA, 2020).

One of the main motivators in choosing this policy as a measure of how successful the United States is doing in comparison with Europe in terms of renewables is that despite this policy only being implemented in the United States, there was still a large amount of growth in renewables in Europe from the years 1990-2015, particularly after 2006 which was when the policy was implemented in the US. While Europe has similar tax credit policies, they were largely implemented in the 1990's which does not explain the sharp increase in renewables post 2006 (Ogunlana, 2016). Analyzing the Investment Tax Credit Policy will give me the opportunity to examine the differences this policy made before and after it was enacted in comparison to Europe and to see if the policy in the US had similar success compared to European tax credit policies.

The Investment Tax Credit Policy is a 26 percent tax credit for solar systems on residential and commercial properties. Additionally, the commercial credit can be applied to both customer-sited commercial solar systems and large-scale utility solar farms. The residential and commercial Investment Tax Credit has helped the US solar industry grow with an average annual growth of 50% over the last decade alone since it was implemented in 2006 (SEIA, 2020). Solar deployment, at both the distributed and utility-scale levels, has grown rapidly across the country and the long-term stability of this federal policy has allowed businesses to continue driving down costs. Eligibility for the Investment Tax Credit is based on a "commence construction" standard, meaning that an owner or operator has either undertaken a continuous program of construction or has entered into a contractual obligation to undertake and complete, within a reasonable time, a continuous program of construction. The residential Investment Tax Credit allows the homeowner to apply the credit to their personal income taxes (SEIA, 2020).

This credit is used when homeowners purchase solar systems and have them installed on their homes. In the case of commercial business credit, the business that installs, develops and/or finances the project claims the credit (SEIA, 2020). This policy helped motivate the choice of outcome variables I will be using to test the effectiveness of this policy in my results section. The two main outcome variables I will be discussing in the paper are: renewable energy consumption and fossil fuel consumption. I chose renewable energy consumption because it is a good indicator if more people in the US started using more renewable energy after this policy was implemented. Additionally, I chose fossil fuel consumption because it is the most common substitute for renewable energy and will help indicate if people started using less of it after this policy was implemented. I will also use two other outcome variables: renewable electricity output and greenhouse gas emissions, however those will be discussed in the appendix because they are not as directly related to what this policy is measuring.

LITERATURE REVIEW

There is a considerable amount of research illustrating the ways in which climate change poses negative economic impacts. The agricultural industry is one of the largest industries in the world that will have severe economic consequences due to climate change. Crops, livestock, and seafood produced in the United States contribute to more than $300 billion in the economy each year and when food-service and other agriculture-related industries are included, the agricultural and food sectors contribute to more than $750 billion in gross domestic product (Hatfield et al, 2014 and USDA, 2016). U.S. farms alone are responsible for nearly 25% of all grains (such as wheat, corn, and rice) on the global market (USDA, 2015), and changes in the frequency and severity of droughts and floods could pose challenges for farmers by making crops much more difficult to grow (Ziska et al, 2014). In 2010 and 2012, high nighttime temperatures affected corn yields across the US Corn Belt, and premature budding due to a warm winter caused $220 million in losses of Michigan cherries in 2012 (Hatfield, 2014). These changes in crop production increase the likelihood that additional tens of millions of people will be at risk of hunger and food security will be severely threatened (Kalin, 2008).

Another major industry that is likely to be significantly impacted by climate change is the fishing industry. American fishermen catch or harvest five million metric tons of fish and shellfish each year, and as of 2012, US fisheries alone contributed to more than $1.55 billion to the economy annually (USDA, 2012). Additionally, marine disease outbreaks have been linked with climate change. Winter warming in the Arctic is contributing to salmon diseases in the Bering Sea and a result, there has been a significant reduction in the Yukon Chinook Salmon species. Changes in temperature and seasons can also affect the timing of reproduction and migration; in the Northwest, warmer water temperatures may affect the lifecycle of salmon and increase the likelihood of disease, which when combined with other climate impacts, it could lead to large declines in salmon populations as a whole (CCSP, 2008 & Romero-Lankao et al, 2014). Salmon's total contribution to the national economy included approximately 32,900 full time employment jobs and $1.7 billion in annual labor income in 2015 and 2016 (McDowell Group, 2017). The salmon industry has one of the greatest economic impacts in terms of jobs, income, and total value among all species in the Alaska seafood industry, and this industry is greatly at risk directly because of climate change.

Climate change not only poses detrimental risks to various economic industries, but it also creates the risk of displacement among many different populations across the world. While climate change itself does not inherently cause displacement, it produces environmental effects which may make it difficult or even impossible for people to survive where they are. Most causes of displacement triggered by climate change, such as flooding, hurricanes, desertification or even the "sinking" of stretches of land, are not new, but their frequency and magnitude are likely to increase as the years go on (Kalin, 2008). Disasters will also increase the need for governments to designate areas as high-risk zones too dangerous for human habitation meaning that people may have to be forcibly evacuated and displaced from their homes. Examples of this could occur because of increased risk of flooding or mudslides due to the thaw of permafrost in mountain regions or along rivers and coastal plains prone to flooding (Kalin, 2008). Displacement not only has severe consequences on individuals' well-being, but there are also significant economic costs and consequences of displacement in areas such as health, shelter, and income. In eight countries, IDMC found that the average cost per internally displaced persons (IDPs) was 310 dollars. With 40 million displaced around the world, the global financial impact of displacement reaches 13 billion dollars annually, which will only continue to increase as more people become displaced from climate change (Yakupitiyage, 2019).

One of the biggest reasons for climate change is the usage of fossil fuels for activities such as transportation and manufacturing. Fossil fuels are the leading substitute good for renewable energy resources like solar, wind, and geothermal energy. Fossil fuel pollution not only damages the health of our planet, but it also negatively impacts human health, especially marginalized communities throughout the world. Human health consequences due to disruptions of physical, biological, and ecological systems include increased respiratory and cardiovascular disease, injuries and premature deaths related to extreme weather events, changes in the prevalence and geographical distribution of food, water-borne illnesses, other infectious diseases, and threats to mental health (CDC, 2020). A healthy population is crucial for a society to have economic progress and growth because healthy populations live longer, are more productive, and save more in the long run (WHO, 2010). Given the lengthy list of detrimental effects and economic costs climate change has on various industries and the human population as a whole, it is apparent that our reliance on fossil fuels needs to be greatly reduced and strides towards renewable energy resources is becoming increasingly important.

There are several major environmental policies in the US for the production of renewables such as the Renewable Energy Credit, the Feed in Tariff, and the Renewable Portfolio Standard. The Renewable Energy Credit is a trading system allowing producers who generate more than their required amount of renewable electricity to sell or trade credits to other suppliers who may not be able to meet their required amount. This policy can also help producers who are still under construction or development (SEC, 2016). The Feed in Tariff policy on the other hand financially compensates customers owning renewable electricity generation facilities such as roof-top solar panels. Customers are compensated for the amount of electricity they provide from renewable facilities to the electric grid which aims to encourage the use of renewable technologies, and thus make them more marketable. While these two policies offer great incentives for companies and households to move towards using renewables, the Renewable Portfolio Standard is the foundation of both of these policies and is a policy that is widely discussed in literature.

Recent literature has explored the Renewable Portfolio Standard (RPS) policy instrument which incentivizes electric companies to increase the share of renewable energy electrification in the electricity market by offering redeemable monetary credit (Delmas, 2011; Carley, 2009). This acts as a foundation to policies such as the Renewable Energy Credit and Feed in Tariff policies that offer incentives after companies or individuals have implemented renewables (SEC, 2016). Carley (2009) evaluates state RPS policy implementation and whether the percentage of renewable energy electricity generation across states increased because of this policy. Similarly, Delmas (2011) also focuses on RPS policy implementation and argues that natural and institutional context rather than the policy might lead to positive outcomes. Examples of this could be a personal decision to move towards renewables due to individual morals or a company wide decision to illustrate corporate responsibility for the health of the planet rather than a government mandated policy implementation. Both papers indicate that RPS implementation is not a significant predictor of the percentage of renewable energy generation.

Another common renewable energy incentive analyzed in literature is the Solar Renewable Energy Credit (SREC) which is a part of the Renewable Portfolio Standard discussed above. Solar Renewable Energy Certificates (SRECs) are a solar incentive that allows homeowners to sell certificates for energy to their utility. A homeowner earns one SREC for every 1000-kilowatt hours (kWhs) produced by their solar panel system and in some states, an SREC can be worth over $300 (EnergySage, 2020). Burns (2012), analyzes the US federal and state level policies in states with solar-targeted policies that have Solar Renewable Energy Credit (SREC) markets. The study finds that SREC markets can be a very strong incentive, but, despite their strong potential as effective renewable policies, the lack of a guaranteed credit minimum and the uncertainty attached with investing in renewables are major drawbacks of SREC markets. To counter this, Burns suggests implementing price floors to reduce the uncertainty of the credit of SREC's, but notes that the value to date of SREC's are roughly equivalent to or just below that of the federal tax credit, a competing environmental policy.

While the RPS and SREC policy instruments incentivize electricity companies and homeowners to produce a certain fraction of their electricity from renewable energy sources by earning certificates, the incentive may not be as strong as a monetary tax incentive could be. Reasons for this are rooted in behavioral economic theories that Congdon (2009) analyzes. Congdon argues that in the case of renewable incentives, loss aversion and the hyperbolic discounting theory would predict that tax credit policies yield better results. A company would see a tax deduction as more impactful because the money they owe is reduced, rather than an SREC credit which is framed as money being gained (companies know they still will have to pay taxes). Additionally, a tax benefit is a more predictable reward because it is a deducted percentage of final taxes rather than SREC credits which need to be earned and redeemed yearly (Congdon, 2009).

Furthermore, investments in renewable energy involve managing the risks and identifying the barriers in renewable energy production and usage. Watts (2011) argues that political, regulatory, and financial risks are on the rise against a backdrop of macro-economic uncertainty, while weather-related volume risk is rising up the agenda as investments in offshore wind farms accelerate. The availability of risk management resources—including risk expertise, industry data, and insurance cover—in the renewable energy sector remains limited, potentially restricting the sector's access to development capital. Beck (2016) argues that the need for enacting policies to support renewable energy is often attributed to a variety of "barriers" or conditions that prevent investments from occurring. Barriers include subsidies for conventional forms of energy, high initial capital costs coupled with lack of fuel-price risk assessment, imperfect capital markets, lack of skills or information, poor market acceptance, technology prejudice, financing risks and uncertainties, high transactions costs, and a variety of regulatory and institutional factors. These barriers negatively affect policy support for renewable energy because "market distortions" unfairly discriminate against renewable energy, while others have the effect of increasing the costs of renewable energy relative to the alternatives. This paper confirms the idea that while there is no perfect incentive in motivating companies to invest in renewables and green energy, direct monetary incentives such as subsidies and tax credits are the most successful in renewable energy development and production.

Additionally, it is important to discuss the relationship with oil and oil prices when analyzing policies affecting the production of renewable energy resources, as oil is the most common substitute good to renewables. Oil is the main and leading competitor of renewable energy resources and is often favored by large corporations due to more competitive prices in the short run, which in turn, often dismisses renewables. Furthermore, it is extremely difficult to compare prices of oil with renewables which further discourages investors from wanting to put their trust in them (Beck, 2016). Sinha (2015) analyzes whether a greater degree of uncertainty caused due to volatility in fossil fuel prices incentivizes governments to increase the share of renewable sources in their overall energy portfolio. In his results, Sinha (2015) finds that increasing oil price volatility is positively associated with renewable energy, meaning that frequent changes and uncertainty of oil prices encourages companies to invest in renewables. Sinha (2015) also states that renewable energy is a strong hedging mechanism that protects economies for global uncertainty in oil prices. Therefore, countries are safeguarded against the rapid fluctuations of both oil prices and exchange rates, which reduces uncertainty and allows for better fiscal and budgetary planning (Sinha, 2015). While it appears that increasing oil price volatility positively affects renewable energy usage and production, this paper fails to mention how tax incentives could influence companies to invest in renewables; this could potentially alter the conclusions about oil price volatility by failing to mention other types of incentives that could contribute positively to the production and usage of renewables. While my paper does not focus on topics regarding oil price volatility, it does focus on tax incentives while also controlling for changes in oil prices from 1990-2015.

Overall, there is a shortage of research on renewable energy tax policy incentives focusing on the United States. In my paper I hope to fill that gap by exploring the Investment Tax Credit Policy on the investment, production, and usage of renewable energy resources in the United States. The current literature largely explores the thought process behind the hesitancy in investing in renewable energy resources in the United States but fails to examine the economic costs that will occur if our society continues to center itself around fossil fuel consumption. My paper corrects for this by doing a cost benefit analysis of shifting infrastructure to fit the usage of renewables within our society, and the economic costs associated if we do not make this shift. Additionally, this paper explores tax credit incentives with a United States context to explore the effectiveness of tax credits in the United States compared to European countries. Europe is one of the biggest competitors and partners to the United States and is very comparable in terms of economic development which is why it was chosen as a benchmark of comparison. The decision to use Europe as a comparison was largely motivated by the amount of literature discussed later in this section which is focused on tax credit policies from a European perspective.

Climate change has been an apparent struggle within the United States, however there have been great strides in the implementation of renewable energy resources within European countries. Kilinc-Ata (2016) examines feed-in tariffs, quotas, tenders, and tax incentives, in promoting renewable energy in 27 EU countries and 50 US states and finds that renewable energy policy instruments, specifically tax incentives, play a significant role in encouraging adoption of renewable energy. Alberini et al. (2015) finds that Italian respondents are more likely to agree to a replacement when the savings on the energy bills are larger and experienced over a longer horizon. However, simply reminding respondents about possible CO_2 emission reductions (a non-monetary incentive) had little effect, further indicating that monetary incentives like tax benefits are more successful in incentivizing the investment and usage of renewable energy resources. Argentiero (2017) analyzes the role of energy policy in investing in renewables based on a carbon tax and price subsidy and finds that in the presence of a total factor productivity shock in the fossil fuel sector, an energy policy involving a carbon tax and a renewable energy source subsidy shows a faster reduction in renewable energy source costs in the E.U.15 compared with in China and the US.

The current literature largely indicates that there has been greater success in environmental policies focused on tax incentives rather than renewable energy credits in encouraging individuals and companies to increase usage of renewables. While studies on the impact of tax credits on renewables have been discussed in a European context, there has been little to no research on the impact of tax credits on renewables in a US context. This paper discusses the Investment Tax Credit Policy, a United States based tax credit policy, on the production and usage of renewable energy resources and whether the implementation of this policy helped close the gap between the US and Europe in terms of the production and usage of renewables. Europe was chosen as a comparison set of countries for my research question as many of the current literature on tax credits is focused with a European context. My paper will give a United States perspective on many European focused tax credit studies and help give an understanding of how these two major economies differ in their production and usage of renewables.

THEORY

In the case of the Investment Tax Credit policy, the government is providing a tax incentive in the form of a tax credit to encourage companies to invest in renewable energy projects and use or provide renewable energy resources as a service. Transitioning to renewable energy would reduce the external costs of climate change due to fossil fuel usage and therefore reduce the costs associated with climate change in major industries such as agriculture and fishing. By reducing the impact of climate change, the agricultural and fishing industries would reduce crop and fishing loss associated with changing weather patterns. This transition would also help increase productivity worldwide by improving the health of our population; increased productivity levels encourages economic growth.

Transitioning to renewables has a large upfront cost because companies must invest and utilize renewable energy resources before getting the opportunity to benefit from the Investment Tax Credit Policy. If companies or individuals do not make the initial investments, they will not receive any kind of a tax break. This paper examines whether the Investment Tax Credit incentivizes companies in the US to move to renewable energy resources. I will use a cost benefit analysis to examine why some companies or individuals choose to transition to renewables and why some choose not to.

The benefits of moving towards renewable energy resources are relatively straightforward in terms of social benefits. Using renewable energy resources is the best way to generate energy without producing greenhouse gas emissions from fossil fuels which would reduce some types of air pollution and therefore reduce the impact of climate change. Additionally, moving towards renewable energy would help create economic development and jobs in manufacturing and installation in the field of renewables (EPA, 2019). This aligns with what is socially optimal because using renewables would reduce the impact of climate change which benefits the health of the planet and therefore human health, as well as creating more jobs for the economy in the renewables industry (EPA, 2019). However, it is more difficult to justify moving towards renewables in terms of private benefits in the absence of environmental tax credit policies. Due to the existing infrastructure designed for a fossil fuel operating country, the private cost of implementing infrastructure to fit renewable technology would lead to reduced profits. However, it is important to note that if renewables did provide private benefits, companies would most likely have moved in that direction without the need for policy intervention.

While there may not be many private benefits in moving towards renewables, the theory of externalities would suggest that the social cost of using non-renewables exceeds the private costs of using renewables. Externalities are the consequence of an industrial or commercial activity that affects other parties without this being reflected in the cost of the goods or services involved. In this case, the usage of fossil fuels comes with the consequence of pollution and climate change. The economic and health risks associated with climate change outweigh the private risk that would come with moving towards renewable energy resources, and therefore despite a temporary potential loss of profit for private firms, it is imperative that we continue our efforts towards investing in renewable energy infrastructure (USDA).

The main cost of moving towards renewable energy resources is the initial capital cost of shifting infrastructure to fit the usage of renewables, and is the main driving factor for its overall failure to widely implement to date. It is extremely difficult to get an accurate assessment of what the cost would be to transition to a 100 percent renewable energy society due to variables such as initial capital costs of shifting infrastructure. Additionally, it is difficult to compare the costs of renewable energy sources with fossil fuels because they are not directly comparable. In addition, there is uncertainty associated with renewable energy such as seasonal variations in productivity, transmission availability, the required discharge rate of storage capacity, the costs of stranded assets, the economic effects of higher electricity prices, the economic effects of levying taxes to subsidize renewable electricity sources, and the higher capital costs of new electricity sources as a mandate spurs new demand (Rossetti et al, 2019). Because of these issues, there is a relatively high uncertainty in estimating an accurate and comparable price for renewables relative to fossil fuels. Additionally, it is estimated that a decarbonized 100 percent renewable electricity system would result in an average electricity cost of $150 per 300 megawatt hour (2017's average electricity cost is $104.8 dollars per megawatt hour). Therefore, a 100 percent renewable electricity grid would require American individuals and companies to pay between 43 and 286 percent more on their electric bills (Rossetti et al, 2019).

This initial capital cost can be seen as a barrier which discourages people from wanting to make this transition. For example, there will be an upfront expense of building and installing solar and wind farms which would require shifting large amounts of already existing infrastructure. However, like most renewables, solar and wind are exceedingly cheap to operate—their "fuel" is free, and maintenance is minimal—so the bulk of the expense comes from simply building the technology (UCSUSA, 2017). Higher construction costs can make financial institutions more likely to perceive renewables as risky and thus charge a higher rate of interest. This makes it harder for utilities or developers to justify the investment. For natural gas and other fossil fuel power plants, the cost of fuel may be passed onto the consumer, lowering the risk associated with the initial investment (UCSUSA, 2017). However, if costs over the lifespan of energy projects are taken into account, wind and solar can be the least expensive energy generating sources (UCSUSA, 2017). As of 2017, the cost before tax credits of wind power was $30-60 per megawatt-hour and large-scale solar cost at $43-53/MWh whereas energy from the most efficient type of natural gas plants cost $42-78/MWh and coal power cost at least $60/MWh (UCSUSA, 2017). Furthermore, renewable energy capital costs have fallen dramatically since the early 2000s, and will likely continue to do so. Between 2006 and 2016, the average value of solar panels themselves plummeted from $3.50/watt to $0.72/watt—an 80 percent decrease in only 10 years (UCSUSA, 2017). Additionally, moving towards renewables would offset the billions of dollars spent fixing losses in infrastructure and food associated with climate change. For example, the $415 billion cost in infrastructure in the last three years due to extreme weather, $220 million in losses of Michigan cherries due to weather pattern changes, and the financial costs of displacement to name a few (Cho, et al, 2019; Hatfield, 2014; Yakupitiyage, 2019).

The long term benefits of transitioning to renewables justifies the initial capital costs that can initially appear as a barrier to those hesitant to make that transition. Some individuals or companies have decided to move towards renewable energy resources; those who choose to "take the risk" and invest in renewables understand the long term impact this will have on our planet and see the high price as an initial capital cost with long term benefits in the future, especially in agriculture, fishing, and human health (USDA).

The SEIA states, "the Investment Tax Credit has proven to be one of the most important federal policy mechanisms to incentivize clean energy in the United States". Therefore, in my analysis, I expect to see a positive impact on the production and usage of renewable energy resources after the Investment Tax Credit Policy was implemented in 2006 in the US. Additionally, I expect to see a sharper increase in renewable energy consumption and a sharper decrease in fossil fuel consumption in the US compared to European countries signifying the effectiveness of this policy relative to Europe.

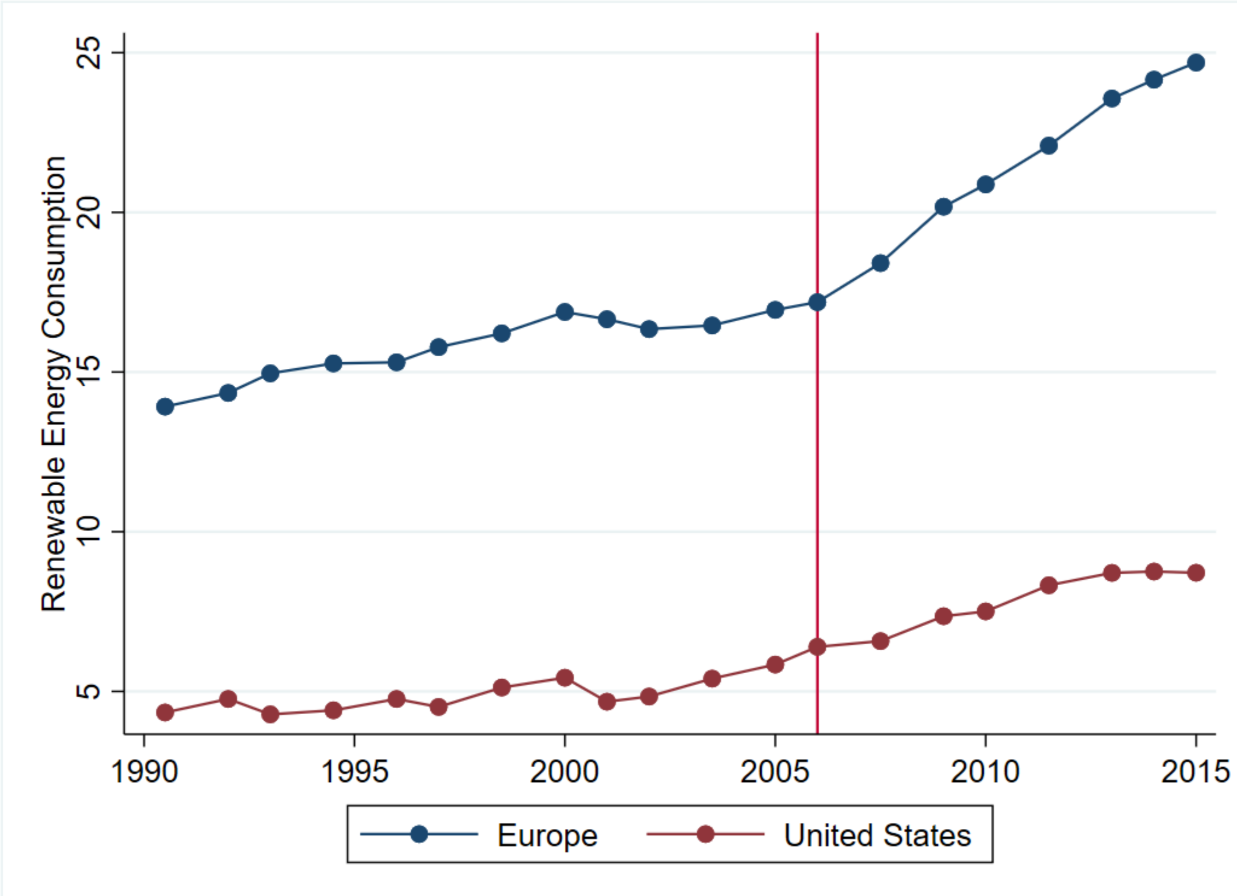
MODEL

For the purpose of my analysis, I will be using a difference in difference model to examine the effect of the Investment Tax Credit policy and the production and usage of renewables in the United States compared to European countries. I chose this model because it will allow me to analyze the effect of this policy before and after it was implemented in 2006 to see if that policy helped close the gap between the US and European countries in terms of increasing the production and usage of renewables. I have four outcome variables that I am using to measure the success of this policy: renewable energy consumption, fossil fuel consumption, renewable electricity output, and greenhouse gas emissions. Theory expects to see a steeper increase in renewable electricity output and renewable energy consumption in the United States after 2006 compared to European countries if the Investment Tax Credit Policy is successful. Similarly, theory expects to see a steeper decrease in fossil fuel consumption and greenhouse gas emissions in the United States after 2006 compared to European countries if the Investment Tax Credit Policy is successful. The basic difference in differences model is shown below:

$$DD = (y_{US\ pre\ 2006} - y_{Europe\ pre\ 2006}) - (y_{US\ post\ 2006} - y_{Europe\ post\ 2006})$$

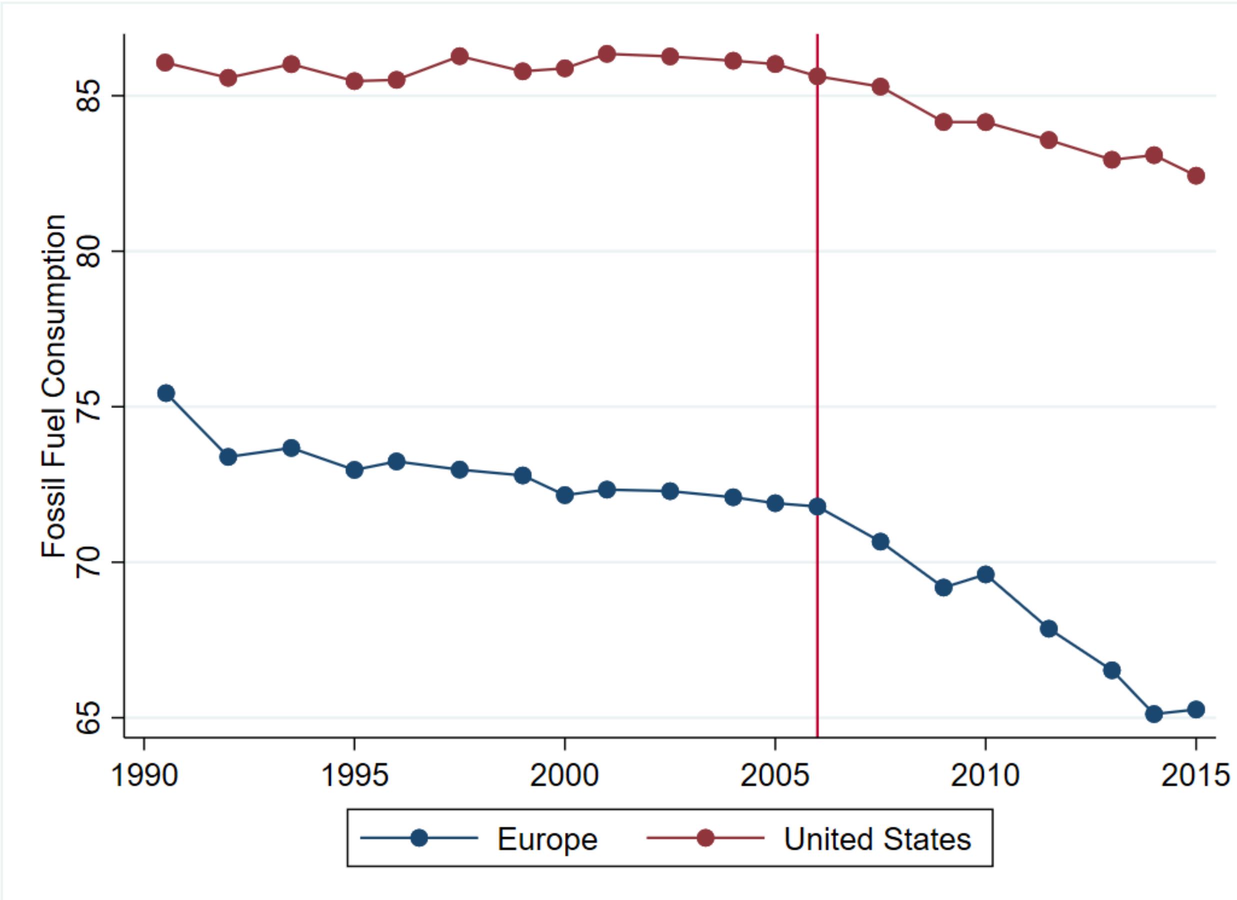
Where DD stands for the difference in difference estimator. 2006 was chosen as the year for the pre and post comparison because that is when the Investment Tax Credit policy was implemented in the US. The US is the treatment group because that is where the policy was implemented, and Europe is the control group because that policy was not implemented there. The graphs below depict a visual interpretation of why controls were necessary for my final models.

Renewable Energy Consumption in US and Europe



Graph 1. This graph shows renewable energy consumption as a % of total energy by year in the US and Europe. The vertical line is where x=2006, which is the year the Investment Tax Credit policy was implemented. While we see an increase in renewable energy consumption in the US, there is a sharper increase in renewable energy consumption in Europe compared to the US after the year 2006. US renewable energy consumption also seemed to follow along its pre 2006 trend, but in Europe there was a sharp increase after 2006. When adding controls, I expect to see a sharper increase in renewable energy consumption in the US post 2006 compared to Europe.

Fossil Fuel Consumption in US and Europe



Graph 2. This graph shows fossil fuel consumption as a % of total energy consumption by year in the US and Europe. The vertical line is where x=2006, which is the year the Investment Tax Credit policy was implemented. While we see a decrease in fossil fuel consumption in the US, there is a sharper decrease in fossil fuel consumption in Europe compared to the US after the year 2006. US fossil fuel consumption seemed to break away from its pre 2006 trend and began decreasing at a faster rate, but compared to Europe the decrease is not as sharp. When adding controls, I expect to see a sharper decrease in fossil fuel consumption in the US post 2006 compared to Europe.

While renewable energy consumption and fossil fuel consumption did increase and decrease in the US after 2006 respectively, the trends in both of these example graphs indicate that the Investment Tax Credit policy alone did not seem to help close the gap between the US and Europe in terms of the production and usage of renewable energy resources. Typically, in a difference in difference analysis, the control group – those observations not directly impacted by the policy in question – should trend similarly after the policy was implemented, however here we see a sharp increase in renewable energy consumption and a sharp decrease in fossil fuel consumption for the control group after 2006. However, these graphs show that this data fulfills the parallel trends assumption, because prior to the implementation of this policy, the trends for the treatment and control countries look similar. What we do know is that prior to the implementation of this policy, Europe and the US were trending similarly which is a key assumption of the difference in difference model. Furthermore, there is the assumption that the US would have followed Europe's trend, all else equal. One of the reasons we may have seen a sharp increase and decrease in renewable energy consumption and fossil fuel consumption respectively is because of the 2008 recession which globally caused oil prices to rise. This and global advances in renewable energy technology may have led to a decrease in US fossil fuel usage even in the absence of the Investment Tax Credit Policy. Additionally, most European tax credit policies were implemented in the 1990's so it cannot be said with certainty why there was also a sharp increase and decrease in renewable energy consumption and fossil fuel consumption respectively post 2006 in Europe (Ogunlana, 2016).

Additionally, I will be running the four different fixed effects panel regressions with control variables to control for other potential factors that may have contributed to these results. My control variables are: urban population, income per capita, unemployment rate, natural gas rents, coal rents, and oil rents. The regression model is shown below:

$$y_{ct} = \beta_0 + \beta_1(treatment_c{*}post_t) + \beta_2(treatment_c) + \beta_3(post_t) + \beta_4(urbanpop_{ct}) + \beta_5(netincomepercap_{ct}) + \beta_6(unemployment_{ct}) + \beta_7(natgasrents_{ct}) + \beta_8(oilrents_{ct}) + \beta_9(coalrents_{ct}) + \alpha_c + \varepsilon_{ct}$$

Where "y_{ct}" are the outcome variables by country by time: renewable energy consumption, fossil fuel consumption, renewable electricity output, and greenhouse gas emissions. The term "treatment*post" is the interaction between the treated country, the United States, and post policy implementation and is the difference in difference estimator. "Post" is a variable that shows post policy effects and varies across time, and "Treatment" is the variable for the treated country, the US. "Urbanpop" is a control variable showing the percentage of the population who lives in an urban area. "Netincomepercap" is a control variable showing the net income per capita. "Unemployment" is a control variable showing the unemployment rate. "Natgasrents", "oilrents", and "coalrents" are also control variables that show the difference between the value of natural gas, oil, and coal production at world prices respectively and total costs of production. Finally, "α_c" is a country intercept term that compares each country's outcome variable relative to the previous year's observation. Additionally, only countries including complete information for every variable and year (1990-2015) were included in these regressions.

DATA

My data was collected from two main sources: the World Bank and the Quality of Government Dataset. I used the World Bank to collect world development indicator variables and renewable electricity output information, and the Quality of Government dataset for data on renewable energy consumption, fossil fuel consumption, and greenhouse gas emissions. My outcome variables are renewable energy consumption, fossil fuel consumption, renewable electricity output, and greenhouse gas emissions. My control variables are urban population, adjusted net national income per capita in current US Dollars, unemployment rate, and rents for natural gas, coal, and oil. Rents are defined as the difference between the value of natural gas, coal, or oil production at world prices respectively and total costs of production. The data spans from the years 1990-2015, however the original datasets had data from 1960-2019. The range of years was reduced because for nearly every variable for all countries, there was a significant amount of missing information before the year 1990 and after the year 2015. Because of this, I reduced the span of years to only include data from 1990-2015.

Additionally, I am using European countries as control countries because many European countries are comparable to the US in terms of net income per capita, unemployment rates, and urban population. Additionally, Europe and the US are frequently compared economically and in terms of development in literature. The United States was chosen as my treated country because this particular policy was only implemented in the United States. While there are 27 countries in the dataset, only 21 countries were used in the regressions with controls because 6 countries had additional missing data points. The control countries are listed below:

Austria, Belgium, Denmark, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom

These European countries were chosen because they have complete information for all the relevant variables for all years. The data is panel data and there are 520 observations in my dataset as a country-year pair for the regressions with controls. Below are tables showing summary statistics for both the US and European countries:

Table 1. *Summary Statistics for Output Variables and Controls in the US*

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
Renewable Electricity Output (% of total electricity)	26	10.16	1.64	6.78	13.23
Renewable Energy Consumption (% of total energy)	26	5.96	1.60	4.09	8.75
Fossil Fuel Consumption (% of total energy)	26	85.23	1.21	82.43	86.46
Greenhouse Gas Emissions (mmbtu)	26	6879152	318024.50	6299766	7351465
Urban Population (% of total population)	26	79.08	1.89	75.30	81.67
Net Income per Capita (US $)	26	33587.98	9056.88	19887.74	49199.66
Unemployment Rate (%)	26	6.10	1.55	3.99	9.63
Natural Gas Rents (% of GDP)	26	0.22	0.17	0	0.54
Coal Rents (% of GDP)	26	0.24	0.14	0.06	0.69
Oil Rents (% of GDP)	26	0.32	0.15	0.01	0.76

Source: University of Gothenburg. "Quality of Government Dataset." 2016
World Bank. "Renewable Electricity Output." 2018
World Bank. "World Development Indicators." 2020

Table 1. shows the summary statistics for output variables and controls in the US.

Table 2. *Summary Statistics for Output Variables and Controls in Europe*

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
Renewable Electricity Output (% of total electricity)	676	28.20	28.78	0	99.99
Renewable Energy Consumption (% of total energy)	676	17.79	16.57	0.61	77.34
Fossil Fuel Consumption (% of total energy)	663	71.27	20.93	10.25	98.53
Greenhouse Gas Emissions (mmbtu)	675	198634.20	248942.20	3323.42	1204779
Urban Population (% of total population)	676	73.39	11.13	47.92	97.88
Net Income per Capita (US $)	624	23832.92	15918.02	979.47	82227.02
Unemployment Rate (%)	661	8.24	4.36	0.64	27.47
Natural Gas Rents (% of GDP)	662	0.11	0.35	0	3.16
Coal Rents (% of GDP)	662	0.06	0.19	0	1.98
Oil Rents (% of GDP)	662	0.34	1.31	0	10.88

Source: University of Gothenburg. "Quality of Government Dataset." 2016
World Bank. "Renewable Electricity Output." 2018
World Bank. "World Development Indicators." 2020

Table 2. shows the summary statistics for output variables and controls in Europe.

The first table shows the summary statistics for outcome variables and controls in the US and the table below shows the summary statistics for outcome variables and controls in Europe. Renewable electricity output and renewable energy consumption are a lower percentage in the

US compared to Europe. Additionally, fossil fuel consumption and greenhouse gas emissions are higher in the US compared to Europe. Finally, net income per capita is higher in the US compared to Europe. This could be attributed to the variety of income per capita in Europe; some European countries are very wealthy while other countries have a lower income per capita compared to the US.

RESULTS

From my initial results, it appears that the Investment Tax Credit policy did little to nothing in closing the gap between the US and Europe in terms of the production and usage of renewable energy resources. Table 3 presents estimates for a difference in difference panel regression testing the effect of the Investment Tax Credit on US renewable energy consumption. The table below outlines the results for the outcome variable: renewable energy consumption.

Table 3. *Effect of Investment Tax Credit Policy on Renewable Energy Consumption in US versus Europe*

Renewable Energy Consumption	Column 1	Column 2	Column 3	Column 4
Treatment*Post	-2.110*	2.747	-2.297*	0.172
	(1.158)	(6.882)	(1.134)	(0.913)
Treatment	0	0	0	0
	(omitted)	(omitted)	(omitted)	(omitted)
Post	4.980***	4.085***	9.748***	4.966**
	(1.158)	(0.921)	(2.282)	(1.964)
Urban Population		-0.222	-0.478*	-0.445*
		(0.179)	(0.286)	(0.284)
Net Income per Capita		0	0	0
		(0)	(0)	(0)
Unemployment Rate		0.201***	0.086	-0.153
		(0.066)	(0.079)	(0.088)
Natural Gas Rents		-3.541	-2.792*	1.965*
		(1.261)	(1.387)	(1.124)
Coal Rents		-3.583*	-1.105	-2.964**
		(1.494)	(1.085)	(1.444)
Oil Rents		0.277	0.586*	0.215
		(0.272)	(0.345)	(0.287)
Constant	15.834***	32.162**	47.076**	44.726**
	(0.424)	(14.617)	(19.847)	(20.025)
r^2	0.021	0.072	0.023	0.019
n	546	520	520	415

Notes: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Column 1 shows the effect of the Investment Tax Credit policy before and after the policy was implemented. Column 2 shows the effect of the Investment Tax Credit Policy before and after the policy was implemented but controlling for variables that may have an impact on renewable energy consumption. Column 3 adds a year fixed effect and a country fixed effect. Column 4 shows a year fixed effect, a country fixed effect, and uses only the years 1990-2010 as a robustness check to account for the sharp increase in renewable energy consumption in European countries after 2010.

Column 1 shows the effect of the Investment Tax Credit policy on use of renewables without any controls. The main coefficients to note are "Treatment*Post" and "Post" because they indicate whether there was an effect on the treated country, the United States. The positive coefficient for "Post" was significant at the 0.01 level and indicates that after the year 2006 for all countries, renewable energy consumption increased. This could indicate that the policy did have an impact on renewables in the US, but since there are no controls for this regression it cannot be said with certainty that this increase in renewable energy consumption can be attributed to the policy. The negative coefficient for "Treatment*Post" in column 1 was significant at the 0.1 level and indicates that the rate of renewable energy consumption in the US decreased compared to the rate of renewable energy consumption in European countries after 2006. From this alone, it can be interpreted that the Investment Tax Credit policy did not help close the gap for renewable energy consumption between the US and European countries. This is because after the policy was implemented, European countries' renewable energy consumption still increased at a faster rate compared to the US despite the policy not being implemented there.

The term "treatment" is omitted in columns 1 and 2 because a fixed-effect panel model in the difference in difference estimation was used. In this model, since whether a country is in the treated or control group is time-invariant and since a fixed-effects panel only looks at changes within a country over time, this regression does not report an estimate for "treatment". In a fixed-effects regression, any variable that is constant within the panel will be collinear with the fixed effect and will be dropped automatically.

However, it is not feasible to only measure the effect of this policy before and after the year 2006 without controlling for other variables that could potentially contribute to these results. Column 2 shows the same regression, but with control variables added. Adding the controls allowed for the results to more accurately reflect the effects of the policy on renewable energy consumption. Again, the coefficients most important to note are "Treatment*Post" and "Post". The "Post" coefficient was positive and significant at the 0.01 level indicating that after the year 2006 for all countries and with controls, renewable energy consumption increased. This shows that the policy could have had an impact on the US alone when not compared with European countries. However, the "Treatment*Post" coefficient was positive but not statistically significant indicating that there is no concrete evidence that the policy truly helped close the gap for renewable energy consumption in the US compared to European countries.

Column 3 adds country and year fixed effects that were not included in the regressions for columns 1 and 2. The country fixed effect will account for all time invariant characteristics of a country that could affect use of renewables. The year fixed effects accounts for shocks that happen at a point in time that will impact the US and European countries in a similar manner. The positive coefficient for “Post” was significant at the 0.01 level indicating that after the year 2006 for all countries, renewable energy consumption increased. This could indicate that the policy had an impact in the US alone. The negative coefficient for “Treatment*Post* was significant at the 0.1 level and indicates that the rate of renewable energy consumption in the US decreased compared to the rate of renewable energy consumption in European countries after 2006. This indicates that after adding a country and year fixed effect, the Investment Tax Credit policy still did not help close the gap for renewable energy consumption between the US and European countries.

Column 4 also has country and year fixed effects but cuts off the data at 2010 rather than 2015. Reducing the years allows for any sharp increases or decreases occurring in European countries to be minimized and offers a better comparison for the US. The “Post” coefficient was positive and significant at the 0.05 level indicating that after the year 2006 for all countries and with controls, renewable energy consumption increased. This shows that the policy could have had an impact on the US alone when not compared with European countries. However, the “Treatment*Post” coefficient was positive but not statistically significant indicating that there is no concrete evidence that the policy truly influenced increasing renewable energy consumption in the US compared to Europe. The table below outlines the results for the outcome variable: fossil fuel consumption.

Table 4. *Effect of Investment Tax Credit Policy on Fossil Fuel Consumption in US versus Europe*

Fossil Fuel Consumption	Column 1	Column 2	Column 3	Column 4
Treatment*Post	2.580**	-0.837	2.945***	1.133
	(1.121)	(5.603)	(1.113)	(0.891)
Treatment	0	0	0	0
	(omitted)	(omitted)	(omitted)	(omitted)
Post	-4.564***	-4.308***	-10.857***	-5.929***
	(1.121)	(0.976)	(2.235)	(2.019)
Urban Population		0.111	0.394	0.334
		(0.183)	(0.269)	(0.311)
Net Income per Capita		0	0	0
		(0)	(0)	(0)
Unemployment Rate		-0.216**	-0.107	-0.105
		(0.081)	(0.086)	(0.131)
Natural Gas Rents		4.433***	3.189**	3.037*
		(1.467)	(1.575)	(1.524)
Coal Rents		3.395**	1.528	2.896
		(1.651)	(1.426)	(1.852)
Oil Rents		-0.571*	-0.783*	-0.583*
		(0.352)	(0.423)	(0.344)
Constant	75.310***	67.505***	49.365***	54.103**
	(0.411)	(13.993)	(18.997)	(22.145)
r^2	0.014	0.044	0.017	0.042
n	546	520	520	415

Notes: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Column 1 shows the effect of the Investment Tax Credit policy before and after the policy was implemented. Column 2 shows the effect of the Investment Tax Credit Policy before and after the policy was implemented but controlling for variables that may have an impact on fossil fuel consumption. Column 3 adds a year fixed effect and a country fixed effect. Column 4 shows a year fixed effect, a country fixed effect, and uses only the years 1990-2010 as a robustness check to account for the sharp decrease in fossil fuel consumption in European countries after 2010.

Similarly, Column 1 shows the effect of the Investment Tax Credit policy on use of renewables without any controls. The negative coefficient for “Post” was significant at the 0.01 level and indicates that after the year 2006 for all countries, fossil fuel consumption decreased. This could indicate that the policy did have an impact on renewables in the US, but since there are no controls for this regression it cannot be said with certainty that this decrease in fossil fuel consumption can be attributed to the policy. The positive coefficient in column 1 for “Treatment*Post” was significant at the 0.05 level and indicates that the rate of fossil fuel consumption in the US increased compared to the rate of fossil fuel consumption in European countries after 2006. From this alone, it can be interpreted that the Investment Tax Credit policy did not help close the gap for fossil fuel consumption between the US and European countries because after the policy was implemented, European countries’ fossil fuel consumption still decreased at a faster rate compared to the US despite the policy not being implemented there. Additionally, the term “treatment” is omitted in columns 1 and 2 for the same reasons as above.

Again, it is not feasible to interpret these results without controlling for other variables that could potentially contribute to these results. Column 2 shows the same regression, but with control variables added allowing for the results to more accurately reflect the effects of the policy on fossil fuel consumption. Again, the coefficients important to note are “Treatment*Post” and “Post”. The “Post” coefficient was negative indicating that after the year 2006 for all countries and with controls, fossil fuel consumption decreased. The “Post” variable was significant at the 0.01 level. The “Treatment*Post” coefficient is negative but not statistically significant indicating that there is no concrete evidence that the policy truly helped close the gap for fossil fuel consumption in the US compared to European countries.

In column 3 the negative coefficient for “Post” was significant at the 0.01 level indicating that after the year 2006 for all countries, fossil fuel consumption decreased. This could indicate that the policy had an impact in the US alone. The positive coefficient for “Treatment*Post* was significant at the 0.01 level and indicates that the rate of fossil fuel consumption in the US increased compared to the rate of fossil fuel consumption in European countries after 2006. This indicates that after adding a country and year fixed effect, the Investment Tax Credit policy did not help close the gap for fossil fuel consumption between the US and European countries.

In column 4 the “Post” coefficient was negative and significant at the 0.01 level indicating that after the year 2006 for all countries and with controls, fossil fuel consumption decreased. This shows that the policy could have had an impact on the US alone when not compared with European countries. However, the “Treatment*Post” coefficient was positive but not statistically significant indicating that there is no concrete evidence that the policy truly had an effect on decreasing fossil fuel consumption in the US compared to Europe even when the data was cut off at 2010.

It is important to note that while this interpretation states that the policy was not effective in closing the gap between the US and European countries, the policy was not intended to get US consumption to track European consumption. When simply looking at the US alone, the policy could theoretically be interpreted as successful because fossil fuel consumption decreased after the year 2006 in the US. However, for the purpose of this paper I am looking at European countries as a reference to compare success against the US. In many pieces of literature, European countries are depicted as being widely successful in the implementation of renewable energy resources and therefore I chose European countries as a benchmark of comparison for the US.

Overall, the use of renewables in the US alone increased after the implementation of the Investment Tax Credit Policy in 2006 and the use of fossil fuels decreased, but it cannot be said with certainty that the implementation of this policy helped close the gap between the US and European countries in usage of renewables. When using European countries as a benchmark of comparison, there is little to no evidence that the Investment Tax Credit Policy had an impact on the production and usage of renewables in the US, but there may have been an impact in the US alone.

The remaining outcome variables: renewable electricity output and greenhouse gas emissions are discussed in the appendix section. Additionally, see appendix for renewable electricity output and greenhouse gas emissions graphs.

CONCLUSION

This paper analyzes the effect of the Investment Tax Credit policy on the production and usage of renewable energy resources in the United States, and whether the implementation of this policy helped close the gap in the production and usage of renewables between the US and European Countries. Four outcome variables were used to measure the effectiveness of this policy relative to European Countries: renewable energy consumption, fossil fuel consumption, renewable electricity output, and greenhouse gas emissions per capita. Had the Investment Tax Credit Policy been successful, we would expect to see a sharper increase in these outcome variables in the United States compared to European Countries. However, my initial results indicated the opposite. In my regressions without controls, both of these outcome variables increased at a slower rate in comparison to European countries, and when controls were added, the coefficients were no longer significant indicating that it cannot be said with certainty that the policy had an impact on these variables. Similarly, for the outcome variables fossil fuel consumption and greenhouse gas emissions per capita, I expected that after the implementation of this policy, there would be a sharper decrease in these variables in the United States compared to European Countries. However, again my initial results indicated the opposite for fossil fuel consumption, but not greenhouse gas emissions. In my regressions without controls, fossil fuel consumption decreased at a slower rate in comparison to European countries, and when controls were added, the coefficients were no longer significant. This indicates that it cannot be said with certainty that the policy impacted fossil fuel consumption, but it may have impacted greenhouse gas emissions. However, my results indicated that there may have been an impact on my outcome variables in the US alone.

These results do not indicate that tax incentives as a whole are not an effective way to move towards renewable energy in the United States, but rather that this specific policy was not successful in motivating companies and households to invest in renewables at the same rate we saw in Europe. Past literature suggests that tax credit incentives in European countries were largely successful in encouraging their population to invest in more renewable energy resources. However, this paper demonstrates that in the United States, tax credit incentives for renewable energy resources do not incentivize our population in the same way that they do for populations in European Countries.

One reason why the Investment Tax Credit policy may have not worked as well in the United States is because the policy stated that the credit would start decreasing in the year 2019 and continue to decrease as time went on (SEIA, 2020). This could be very discouraging to people who already see the initial capital costs of changing infrastructure to accommodate renewable energy resources as too pricey. By 2021, the residential tax credit drops to 0% whereas the commercial tax credit drops to a permanent 10% from the original 26% for both categories (SEIA, 2020). Despite the policy being extremely popular when it was first implemented, and its success in the US alone, the decrease in value of the tax credit over time could be enough to discourage people from even considering making this change. Future research could explore how specific policies on a state level could impact the production and usage of renewables in the United States. Because the United States greatly varies in government and policy on a state by state level, certain policies in certain states could sway the overall appearance of the US's efforts to move towards renewables. By examining data on a state level, individual states and policies could be targeted as states that are moving towards renewable energy resources and states that are largely opposed. Additionally, it could be interesting to look at the effect of the Investment Tax Credit Policy using company level data to see if it encouraged private US firms to increase their production and usage of renewables.

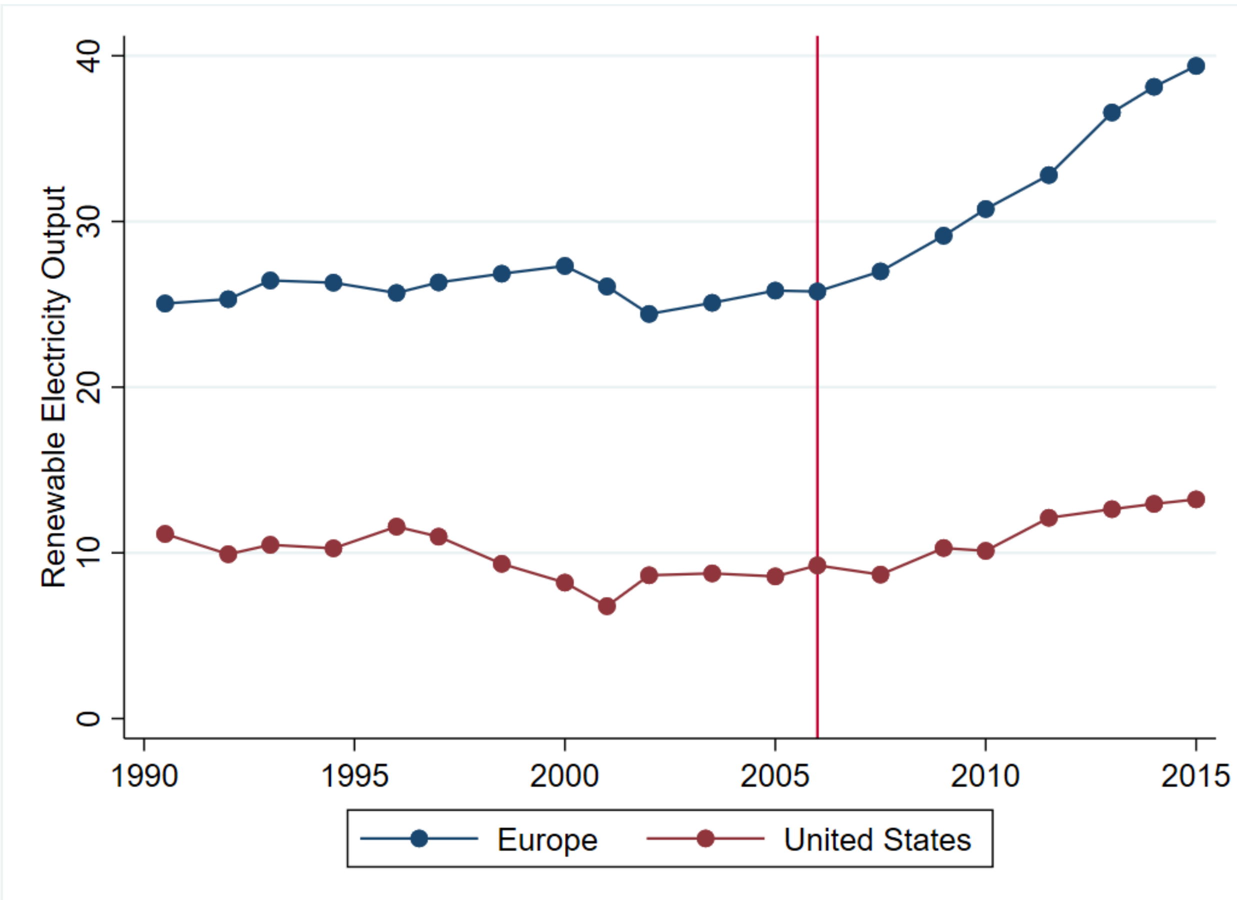
A limitation in my research was getting data for both the United States and for European countries. Initially I wanted to explore the United States on a state by state level in comparison to European countries. My reasoning in this was states in the United States differ so greatly in terms of government and policy that they almost act like separate countries such as in Europe. This would have also given me significantly more observations in my treatment group, the United States. However, it was extremely difficult to find data with the same variables on a country level in Europe and with state level in the United States. Because of this, it was not possible for me to extend my research to examine the United States on a state by state level in comparison to European countries, however it could be a potentially interesting avenue for further research. Additionally, there was little to no research on this particular policy and the effectiveness of it within the United States. Most of the initial research that was conducted prior to collecting my data was examining the effectiveness of tax credit policies with a European context. Because of this, the theoretical foundations for this research question were extremely sparse for a United States context.

While the Investment Tax Credit Policy in the United States was popular and somewhat successful in its initial years, when comparing it to other largely developed countries in Europe, it can be concluded that this policy did little to nothing in helping close the gap between the United States and European countries in the production and usage of renewable energy resources. Both the United States and Europe increased their overall renewable energy consumption, however, the United States increased at a much slower rate overall despite the Investment Tax Credit Policy being implemented only in the US.

APPENDIX

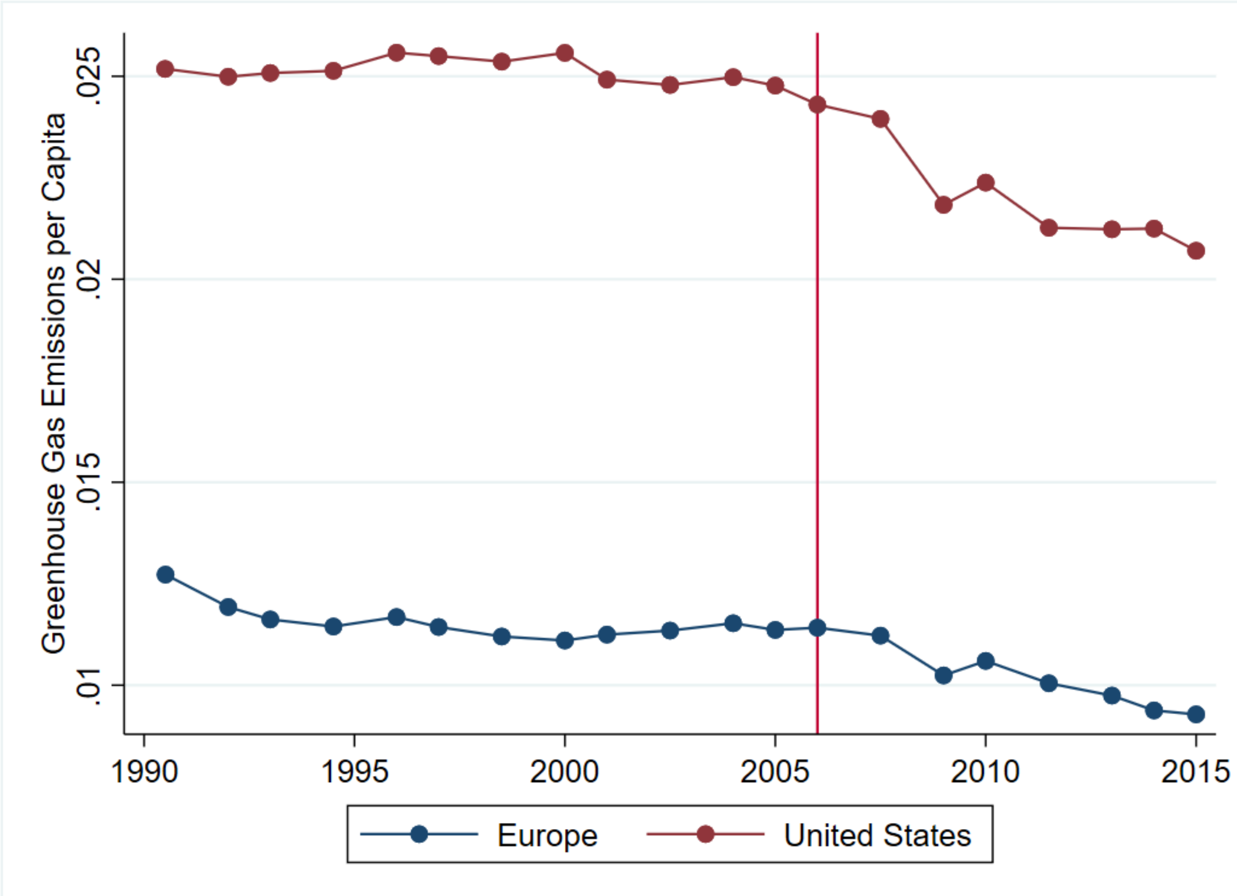
The graphs below depict a visual interpretation of why controls and country/year fixed effects were necessary for my final models.

Renewable Electricity Output in US and Europe



Graph 3. This graph shows renewable electricity output as a % of total electricity by year in the US and Europe. The vertical line is where x=2006, which is the year the Investment Tax Credit policy was implemented. We see a sharper increase in renewable energy output in Europe compared to the US after the year 2006. US renewable electricity output also seemed to follow along its pre 2006 trend, but in Europe there was a sharp increase after 2006.

Greenhouse Gas Emissions per Capita in US and Europe



Graph 4. This graph shows greenhouse gas emissions per capita in the US and Europe. The vertical line is where x=2006, which is the year the Investment Tax Credit policy was implemented. We see a sharper decrease in greenhouse gas emissions in the US compared to Europe after the year 2006 indicating it broke away from its pre 2006 trend, but the amount of greenhouse gas emissions in the US is still much higher than in Europe.

Below are the set of results for the remaining outcome variables: renewable electricity output and greenhouse gas emissions. Table 5 presents estimates for a difference in difference panel regression testing the effect of the Investment Tax Credit on US renewable electricity output.

Table 5. *Effect of Investment Tax Credit Policy on Renewable Electricity Output in US versus Europe*

Renewable Electricity Output	Column 1	Column 2	Column 3	Column 4
Treatment*Post	-4.673**	3.000	-5.371**	-1.437
	(1.773)	(10.996)	(2.467)	(2.001)
Treatment	0	0	0	0
	(omitted)	(omitted)	(omitted)	(omitted)
Post	6.043***	7.004***	20.094***	9.629**
	(1.773)	(1.706)	(4.956)	(4.281)
Urban Population		0.085	-0.395	-0.330
		(0.291)	(0.523)	(0.542)
Net Income per Capita		0	0	0
		(0)	(0)	(0)
Unemployment Rate		0.378**	0.108	-0.268
		(0.152)	(0.139)	(0.199)
Natural Gas Rents		-3.223	-1.038	0.362
		(2.834)	(3.069)	(2.645)
Coal Rents		-6.097*	-0.605	-3.383
		(3.255)	(2.183)	(3.032)
Oil Rents		1.102	1.736*	1.079
		(0.812)	(1.006)	(0.847)
Constant	27.526***	24.417	53.032	50.361
	(0.649)	(25.565)	(36.883)	(38.936)
r^2	0.013	0.068	0.070	0.129
n	546	520	520	415

Notes: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Column 1 shows the effect of the Investment Tax Credit policy before and after the policy was implemented. Column 2 shows the effect of the Investment Tax Credit Policy before and after the policy was implemented but controlling for variables that may have an impact on renewable electricity output. Column 3 adds a year fixed effect and a country fixed effect. Column 4 shows a year fixed effect, a country fixed effect, and uses only the years 1990-2010 as a robustness check to account for the sharp increase in renewable electricity output in European countries after 2010.

Column 1 shows the effect of the Investment Tax Credit policy on use of renewables without any controls. The positive coefficient for “Post” was significant at the 0.01 level and indicates that after the year 2006 for all countries, renewable electricity output increased. This could indicate that the policy did have an impact on renewables in the US, but since there are no controls for this regression it cannot be said with certainty that this increase in renewable electricity output can be attributed to the policy. The negative coefficient in column 1 for “Treatment*Post” was significant at the 0.05 level and indicates that the rate of renewable electricity output in the US decreased compared to the rate of renewable electricity output in European countries after 2006. From this alone, it can be interpreted that the Investment Tax Credit policy did not help close the gap for renewable electricity output between the US and European countries because after the policy was implemented, European countries’ renewable electricity output still increased at a faster rate compared to the US despite the policy not being implemented there. Additionally, the term “treatment” is omitted in columns 1 and 2 for the same reasons as the results section indicate.

Again, it is not feasible to interpret these results without controlling for other variables that could potentially contribute to these results. Column 2 shows the same regression, but with control variables added allowing for the results to more accurately reflect the effects of the policy on renewable electricity output. Again, the coefficients important to note are “Treatment*Post” and “Post”. The “Post” coefficient was positive indicating that after the year 2006 for all countries and with controls, renewable electricity output increased. The “Post” variable was significant at the 0.01 level. The “Treatment*Post” coefficient is positive but not statistically significant indicating that there is no concrete evidence that the policy truly had an effect on renewable electricity output in the US compared to European countries.

In column 3 the positive coefficient for “Post” was significant at the 0.01 level indicating that after the year 2006 for all countries, renewable electricity output increased. This could indicate that the policy had an impact in the US alone. The negative coefficient for “Treatment*Post* was significant at the 0.05 level and indicates that the rate of renewable electricity output in the US decreased compared to the rate of renewable electricity output in European countries after 2006. This indicates that after adding a country and year fixed effect, the Investment Tax Credit Policy did not help close the gap for renewable electricity output between the US and European countries.

In column 4 the “Post” coefficient was positive and significant at the 0.05 level indicating that after the year 2006 for all countries and with controls, renewable electricity output increased. This shows that the policy could have had an impact on the US alone when not compared with

European countries. However, the “Treatment*Post” coefficient was negative but not statistically significant indicating that there is no concrete evidence that the policy truly had an effect on increasing renewable electricity output in the US compared to Europe even after the data was cut off in 2010. The table below outlines the results for the outcome variable: greenhouse gas emissions.

Table 6. *Effect of Investment Tax Credit Policy on Greenhouse Gas Emissions in US versus Europe*

Greenhouse Gas Emissions	Column 1	Column 2	Column 3	Column 4
Treatment*Post	-0.002***	-0.002	-0.001***	-0.001***
	(0)	(0.002)	(0.001)	(0)
Treatment	0	0	0	0
	(omitted)	(omitted)	(omitted)	(omitted)
Post	-0.001***	0***	-0.002*	0
	(0)	(0)	(0.001)	(0.001)
Urban Population		0	0	0
		(0)	(0)	(0)
Net Income per Capita		-5.01E-08***	-6.39E-08**	-6.59E-08***
		(1.84E-08)	(2.88E-08)	(1.77E-08)
Unemployment Rate		0***	0	0*
		(0)	(0)	(0)
Natural Gas Rents		0.001**	0.001**	0.001*
		(0)	(0)	(0)
Coal Rents		0.001*	0	0
		(0)	(0.001)	(0.001)
Oil Rents		0	0	5.20E-06
		(0)	(0)	(0)
Constant	0.012***	0.017***	0.015**	0.015**
	(0)	(0.006)	(0.007)	(0.006)
r^2	0.003	0.026	0.034	0.145
n	546	520	520	415

Notes: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Column 1 shows the effect of the Investment Tax Credit policy before and after the policy was implemented. Column 2 shows the effect of the Investment Tax Credit Policy before and after the policy was implemented but controlling for variables that may have an impact on greenhouse gas emissions. Column 3 adds a year fixed effect and a country fixed effect. Column 4 shows a year fixed effect, a country fixed effect, and uses only the years 1990-2010 as a robustness check to account for the sharp decrease in greenhouse gas emissions in European countries after 2010.

Similarly, Column 1 shows the effect of the Investment Tax Credit policy on use of renewables without any controls. The negative coefficient for “Post” was significant at the 0.01 level and indicates that after the year 2006 for all countries, greenhouse gas emissions decreased. This could indicate that the policy did have an impact on renewables in the US, but since there are no controls for this regression it cannot be said with certainty that this decrease in greenhouse gas emissions can be attributed to the policy. The coefficient for “Treatment*Post” was negative and significant at the 0.01 level indicating that greenhouse gas emissions per capita in the US decreased more compared to Europe after 2006. From this alone, it can be interpreted that the Investment Tax Credit policy did help slightly close the gap for greenhouse gas emissions per capita between the US and European countries because after the policy was implemented, European countries’ greenhouse gas emissions decreased at a slightly slower rate compared to the US. Additionally, the term “treatment” is omitted in columns 1 and 2 for the same reasons as above.

Again, it is not feasible to interpret these results without controlling for other variables that could potentially contribute to these results. Column 2 shows the same regression, but with control variables added allowing for the results to more accurately reflect the effects of the policy on greenhouse gas emissions. Again, the coefficients important to note are “Treatment*Post” and “Post”. The “Post” coefficient was negative (with more decimals) indicating that after the year 2006 for all countries and with controls, greenhouse gas emissions decreased. The “Post” variable was significant at the 0.01 level. The “Treatment*Post” coefficient is negative but not statistically significant indicating that there is no concrete evidence that the policy truly had an effect on greenhouse gas emissions in the US compared to European countries when controls are added.

In column 3 the negative coefficient for “Post” was significant at the 0.1 level indicating that after the year 2006 for all countries, greenhouse gas emissions decreased. This could indicate that the policy had an impact in the US alone. The negative coefficient for “Treatment*Post* was significant at the 0.01 level and indicates that the rate of greenhouse gas emissions in the US increased compared to the rate of greenhouse gas emissions in European countries after 2006. This indicates that after adding a country and year fixed effect, the Investment Tax Credit policy did help close the gap for fossil fuel consumption between the US and European countries.

In column 4 the “Post” coefficient was negative (with more decimals) and not statistically significant indicating that it cannot be said with certainty that greenhouse gas emissions decreased after the year 2006. The “Treatment*Post” coefficient was negative and significant at the 0.01 level indicating that the Investment Tax Credit Policy helped close the gap between the US and Europe in decreasing greenhouse gas emissions when the data was cut off at 2010.

This further illustrates that the use of renewables in the US alone increased after the implementation of the Investment Tax Credit Policy in 2006. Additionally it cannot be said with certainty that the implementation of this policy helped close the gap between the US and European countries in usage of renewables but it may have helped close the gap in decreasing greenhouse gas emissions. When using European countries as a benchmark of comparison, there is little to no evidence that the Investment Tax Credit Policy had an impact on the production and usage of renewables in the US overall.

RESOURCES

Alberini, Anna, and Andrea Bigano. "How effective are energy-efficiency incentive programs? Evidence from Italian homeowners." *Energy Economics* 52 (2015): S76-S85.

Argentiero, Amedeo, et al. "Comparing Renewable Energy Policies in EU-15, US and China: A Bayesian DSGE Model." *The Energy Journal* 38.KAPSARC Special Issue (2017).

"Barriers to Renewable Energy Technologies." *Union of Concerned Scientists*, Dec. 2017, www.ucsusa.org/resources/barriers-renewable-energy-technologies.

Beck, Fred, and Eric Martinot. "Renewable energy policies and barriers." (2016).

Burns, John Edward, and Jin-Su Kang. "Comparative economic analysis of supporting policies for residential solar PV in the United States: Solar Renewable Energy Credit (SREC) potential." *Energy Policy* 44 (2012): 217-225.

Carley, Sanya. "State renewable energy electricity policies: An empirical evaluation of effectiveness." *Energy policy* 37.8 (2009): 3071-3081.

CCSP (2008). *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Chapter 3. Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (authors). U.S. Environmental Protection Agency, Washington, DC, USA.

Cho, Renee | June, et al. "How Climate Change Impacts the Economy." *State of the Planet*, Columbia University, 20 June 2019, blogs.ei.columbia.edu/2019/06/20/climate-change-economy-impacts/.

"Climate Change and Public Health - Climate Effects on Health." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 21 Aug. 2020, www.cdc.gov/climateandhealth/effects/default.htm.

Congdon, William, Jeffrey R. Kling, and Sendhil Mullainathan. *Behavioral economics and tax policy*. No. w15328. National Bureau of Economic Research, 2009.

"Current State of U.S. Renewable Energy Policy." Sustainable Energy Coalition, 2 June 2016, sustainableenergy.org/current-state-of-u-s-renewable-energy-policy/.

Delmas, Magali A., and Maria J. Montes-Sancho. "US state policies for renewable energy: Context and effectiveness." *Energy Policy* 39.5 (2011): 2273-2288.

Goodward, Jenna, and Mariana Gonzalez. "Bottom Line on Renewable Energy Tax Credits." *World Resources Institute*, 26 Sept. 2018, www.wri.org/publication/bottom-line-renewable-energy-tax-credits.

"Health and Development." *World Health Organization*, World Health Organization, 9 Dec. 2010, www.who.int/hdp/en/.

IPCC (2014). Romero-Lankao, P., J.B. Smith, D.J. Davidson, N.S. Diffenbaugh, P.L. Kinney, P. Kirshen, P. Kovacs, and L. Villers Ruiz, 2014: *North America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1439-1498.

Kalin, Walter. "Displacement Caused by the Effects of Climate Change: Who Will Be Affected and What Are the Gaps in the Normative Framework for Their Protection?" 10 Oct. 2008, doi:https://www.brookings.edu/research/displacement-caused-by-the-effects-of-climate-change-who-will-be-affected-and-what-are-the-gaps-in-the-normative-framework-for-their-protection/#:~:text=Rather%20climate%20change%20produces%20environmental,2%5D%2C%20are%20not%20new.

Kilinc-Ata, Nurcan. "The evaluation of renewable energy policies across EU countries and US states: An econometric approach." *Energy for Sustainable Development* 31 (2016): 83-90.

"Local Renewable Energy Benefits and Resources." *EPA*, Environmental Protection Agency, 13 Aug. 2019, www.epa.gov/statelocalenergy/local-renewable-energy-benefits-and-resources.

McDowell Group. "The Economic Value of Alaska's Seafood Industry." *Alaska Seafood*, Sept. 2017, The Economic Value of Alaska's Seafood Industry.

Ogunlana, Ayodele. "Tax Incentives for Renewable Energy: The European Experience." *The European Proceedings of Social and Behavioral Species*, 2016, www.europeanproceedings.com/files/data/article/50/1579/article_50_1579_pdf_100.pdf.

Rossetti, Philip, et al. "What It Costs to Go 100 Percent Renewable." *AAF*, 25 Jan. 2019, www.americanactionforum.org/research/what-it-costs-go-100-percent-renewable/.

Sinha, Akshay K. "The Effect of Oil Price Volatility on Renewable Energy Production." *Georgetown University* (2015).

"Solar Investment Tax Credit (ITC)." *SEIA*, 2020, www.seia.org/initiatives/solar-investment-tax-credit-itc.

"SRECs: Understanding Solar Renewable Energy Credits." *EnergySage*, 2020, www.energysage.com/solar/cost-benefit/srecs-solar-renewable-energy-certificates/.

University of Gothenburg. “Quality of Government Dataset.” 2016, https://qog.pol.gu.se/data/datadownloads/qogoecddata

USDA (2012). *2012 Census of Agriculture: Volume 1, Chapter 1: U.S. National Level Data, Table 33*. U.S. Department of Agriculture.

USDA (2015). *World Agriculture Supply and Demand Estimates*. U.S. Department of Agriculture.

USDA (2016). Economic Research Service, undated. What is Agriculture’s Share of the Overall US Economy?

US EPA (2016). *Climate Change Indicators in the United States: A Closer Look: Marine Species Distribution*.

USGCRP (2014). Hatfield, J., G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall, and D. Liverman, 2014: *Ch. 6: Agriculture. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 150-174.

USGCRP (2014). Ziska, L., A. Crimmins, A. Auclair, S. DeGrasse, J.F. Garofalo, A.S. Khan, I. Loladze, A.A. Pérez de León, A. Showler, J. Thurston, and I. Walls, 2016: *Ch. 7: Food Safety, Nutrition, and Distribution*. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 189–216.

Watts, C., and A. Freudmann. "Managing the risk in renewable energy." *The Economist* (2011).

World Bank. “Renewable Electricity Output.” 2018, https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS

World Bank. “World Development Indicators.” 2020, https://datacatalog.worldbank.org/dataset/world-development-indicators

Yakupitiyage, Tharanga. “The Hidden Economic Costs of Displacement.” *The Hidden Economic Costs of Displacement | Inter Press Service*, 2019, www.ipsnews.net/2019/02/hidden-economic-costs-displacement/.