Research Article

Green Energy Policies and the Energy Sector: An OLS and Fixed Effect Regression Approach to Economic Impact

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ABSTRACT

With climate change on the rise, causing harm all across the globe, it has become imperative, now more than ever, to transfer to green energy from nonrenewables to decrease global emissions. This paper will analyze the impacts of green energy and specific green energy policies on economic growth, determining the best green energy initiative that will work for countries with varying economic structures to minimize short-term impacts. We will analyze these energy sectors with an Ordinary Least Squares (OLS) regression, with Gross Domestic Product (GDP) Growth as our dependent variable and the energy sector, fixed effects, and control groups as our x variables. Through this analysis, we found that nonrenewables significantly negatively impact economic growth, while renewable energy is more likely to impact GDP positively. We also found that subsidy programs are the best policies for countries to maintain economic growth. With these findings, we can further contribute towards creating a suitable course of action to safely create a green transition and reach net zero by 2050.

Keywords: Green Energy Economics; Economics; Sustainability; Energy Economics; Sustainable Development; Policies

INTRODUCTION

Our society has dealt with many problems; however, none come even close to the pinnacle of human harm: climate change. Rising temperatures, severe weather patterns, higher sea levels–the list goes on and on as to how global warming affects us all. This paper will attempt to analyze the most harmful impact: health risks. One significant, if not the most prominent, contributor to climate change is our use of fossil fuels. Releasing over 30 billion tons of carbon dioxide per year, fossil fuel extraction has caused temperatures to increase rapidly in every part of the globe, from the towering cities on the U.S. East Coast to the dry expanse of the Sahara Desert (1). With temperatures heating up fast and economic growth razing nearby ecosystems, it becomes imperative to understand the tension between the need for energy production and the long-term risks of environmental, economic, and social harm to devise a plan forward. Otherwise, we may face severe resource depletion and inhabitable environments across the globe.

However, despite the severe consequences of industrialization and emissions from fossil fuel energy,

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Received February 11, 2025**; Accepted** March 17, 2025
https://doi.org/10.70251/HYJR2348.321325

economic growth can also be a solution to achieve net-zero emissions by 2050 through innovation, green technologies, and more robust alternatives to the current energy sources. Notably, the most significant way to reduce carbon emissions is shifting to renewable energy solutions such as wind-, hydroelectric-, and solar energy sources that do not release carbon dioxide and particulate matter emissions. The United Nations reports that the nonrenewable energy sector of the economy is the leading cause of global warming, so by reducing emissions from this sector, we can slow the rise of temperatures and even lower the greenhouse gas concentration in the atmosphere (2).

Unfortunately, it is not simple to shift to renewables. Every country has a different economic system and differing economic stability, and renewable energy sources are expensive. Advanced economies like the United States may be able to fund the significant transition to renewable energy, but developing countries such as South Sudan, Chad, and the Democratic Republic of Congo do not have the economic capacity to enforce these green policies. Thus, this research paper will focus on analyzing policies centering on transitions to renewable energy that have been implemented over the past few decades by countries with various environmental and economic stability levels, determining which policies are the most viable to maintain a stable economy while responding to environmental threats such as pollution and climate change from oil and coal energy generation.

First, to be successful, green policies that support energy transition must work for countries with either low or high economic stability. Thus, analyzing green policies in different countries will help determine whether or not these shifts are compatible with countries with varying degrees of economic stability across the globe, increasing the likelihood that our results are extrinsically valid. This paper will analyze countries in different continents and regions to account for the differences in economic stability, particulate matter concentration, wind patterns, and local region characteristics to help increase variation for more promising results. Specifically, this paper will analyze green policies in Australia, Brazil, Canada, Denmark, The Netherlands, South Africa, Sweden, and Uruguay.

I identified policies enacted from 2000 to 2020 related to significant transitions to renewable energy in these countries, as many countries have started taking the initiative to respond to global warming with such policies in recent years. Then, I selected a time frame starting from when the country enacted this policy to ensure that we record the maximum amount of changes caused by the policy using the data recorded before implementation as a benchmark. We first analyze the change in the country's energy makeup through this time frame. Our hypothesis for this data set is that if the green policy is successful, it will have been enforced and caused some change in a particular energy source used by the country, whether it be a decrease in nonrenewable use or an increase in renewable use. The green policies must affect both the intensive and extensive margin of energy, decreasing the extraction of current energy sources and the opposite for renewables, as well as the decrease of nonrenewable sites and the increase in renewable sites, respectively. With the data from the International Energy Agency's (IEA) data on energy across different countries, we now measure the change in energy production in terajoules in these new categories (3). If it also or only focuses on reducing nonrenewables, I measure the change in energy production in terajoules for the nonrenewable sources affected by the policy. By doing so, we can confirm that the green policy enacted was enforced and impacted the sources of energy it was expected to change.

The World Health Organization explains that countries have already taken measures to reduce particulate matter through the general path to reducing pollution (4). Still, countries must take more action to prevent hundreds of thousands, if not millions, of deaths per year. One causal factor of these emissions is nonrenewable energy sources, especially burning fossil fuels. These factories release particulate matter, a mixture of solid particles and liquid droplets found in the air, many of which are harmful to the human body (5). Thus, Particulate Matter (PM) 2.5 and PM 10 concentrations present significant consequences when determining if energy transition policies are effective, with decreasing nonrenewables leading to economic costs within the region, causing the energy sector to impact local economies indirectly. However, we must also consider the pollution that could have traveled from other countries with their nonrenewable energy emissions.

I must also measure the effect of green policies on the economy because economic stability is necessary for countries to carry out essential initiatives and help solve problems other than the one discussed in this paper. The economy is also a crucial factor in maintaining people's standard of living, so government green policies must have minimal impact on economic growth to be effective. According to a recent analysis by the IEA, the clean energy sector alone contributed approximately \$320 billion to the global economy in 2023, representing roughly 10% of global GDP growth, meaning any changes in energy makeup will significantly impact a country's economy (6). To consider the economic side of these green policies, we will use change in GDP growth measured in percentage over our selected timeframe for each country.

This paper predicts that the green policy will succeed if it minimally affects or promotes economic growth. Suppose GDP growth decreases significantly throughout the period. In that case, the green policy will be unsuccessful if implemented in countries with weaker economies. If any other outcome occurs, this green policy will be successful, have little impact on the economy, and potentially be enforced by countries with weaker economic stability. With these three data sets, I accurately determined 1) whether the policy changed to renewable energy sources from nonrenewables, 2) whether reduced nonrenewables will lower economic costs from pollution, and 3) whether the policy had minimal impact on the economy. If all these statements are proven true for a green policy, this policy will be successful and able to be implemented in countries with high or low economic stability. Thus, I used the most substantial green policies to formulate a plan to accomplish these goals and bring us closer to net zero by the year 2050, as the United Nations deems net zero this year to be the most effective for mitigating climate change impacts (7).

Literature Review

Several pieces of literature have explored the three-way intersection of public policy, economics, and pollution reduction, and for good reason. Ensuring all countries work collectively towards achieving net zero by 2050 is essential to protecting modern societies. When addressing the energy industry specifically, countries must find a way to enact policies that balance their economy, their production of energy, and their desperate need to stray from pollutant-emitting energy sources towards their green alternatives. Researchers have analyzed the relationship between public policy and pollution mitigation utilizing different measuring strategies. Past research has attempted to measure the benefits of green policies in primarily two ways.

First, some researchers have measured the impact specific green policies have had on reducing pollutants, whether it being carbon dioxide, particulate matter, or other forms of pollution, and their effects on the environment and essential health (8). Secondly, other papers have identified the importance of green policy impacts on economic conditions, as maintaining government revenue is vital for sustaining current policies and acts that support education, public services, and other factors of Gross Domestic Product (GDP) Growth (9). However, decreasing nonrenewable energy use has already been shown to decrease pollution. In contrast, renewable energy policies can harm the economy if not administered correctly, following its indirect impact of a decrease in nonrenewable energy.

Relationship between green policies and pollutant emissions

Most, if not all, green policies aim to reduce climate change and pollution. This leading driver of renewable energy creation has led to many studies examining past green policies to identify strengths and weaknesses and present or suggest a more effective plan for future energy laws. There are various ways to explore the impacts of green policies on pollution reduction; however, some might be better than others. For instance, several research papers have analyzed the change in carbon dioxide emissions due to green policies. Shuguang Wang's paper on the carbon emission reduction effect of green fiscal policy attempts to utilize a Difference-in-Differences Model to explore the impact of energy conservation and emission reduction (ECER) policies on carbon emissions (CE1) and carbon efficiency (CE2), finding they were significant to the reduction of carbon emissions (10).

Furthermore, Sheng Li's research on the role of renewable energy and fiscal policy on trade-adjusted carbon emissions utilizes a novel panel asymmetric ARDL test to identify environmental policy strictness on consumption-based carbon emissions. Both papers examine energy transitions to reduce carbon emissions (11); however, both present issues: 1) carbon emissions come from several producers other than the energy industry (climate.gov), and 2) carbon emissions diffuse into the atmosphere, leading to potential climate impacts on a global scale rather than a more localized effect. This can lead to quite significant amounts of error as both studies have limited the number of sources they measure for carbon pollutants and carbon emission harms could come from places outside of the country whose policy is in question. There is literature that has instead focused on the effects of particulate matter emissions rather than carbon dioxide, such as PM 2.5. However, while PM 2.5 does not travel as far or as fast as carbon dioxide, it can also travel considerable distances due to wind, and PM10 is far more localized than the other pollutants (12).

In addition, Yasir Khan's analysis of the impact of green energy solutions on PM emissions in Organization for Economic Cooperation and Development (OECD) countries reports that excluding economic growth, green energy solutions reduce particulate matter.[13] These analyses find that a decrease in nonrenewables lead to a reduction of pollution and vice versa. We can say the opposite about renewable energy due to the green energy policies decreasing people's reliance on nonrenewable energy, leading to a decrease in nonrenewable energy production. Because energy systems are reliant on the economy for construction and use and vice versa for essential economic function, a more suitable indicator of the policy's success is its economic impact, making it necessary to determine if such initiatives can work in countries with varying economic structures and economic strengths, as well as the willingness of politicians to enact such policies that may have little benefit to themselves.

Relationship between green policies and economies

A concept that many studies may overlook is the impact that green policies have on economics. Khan's analysis only focuses on OECD countries, which are reported to have relatively strong and high-income economies (13). Lei Ma's analysis of the economic impacts of green energy transitions reports that green growth is positive for most industrialized countries (14). However, mitigating pollution is a global effort, and a just transition to green energy requires all countries to be able to implement it, regardless of economic strength. This pertains to an energy solution that works not just in industrialized empires but also in rural and developing countries, ensuring that emissions are reduced worldwide for a complete transition to clean energy. The energy industry is also a significant revenue generator for the countries I analyze in this paper and a massive contributor to GDP categories such as basic and research and development (R&D) investment. Control factors should allow us to thoroughly explore the impacts of changes in energy on GDP growth, and analyzing several countries with varying approaches to green transitions will help achieve confirmation that specific green policies will work in countries with varying sizes of economies. Thus, studying the convergence of public policy, the need for green energy, particulate matter reduction, and economic stability is necessary to stand a chance against the global threat of climate change.

Theory

The energy industry, both renewable and nonrenewable, has become the backbone of daily societal function. This industry powers almost every proper mechanism we have today, from traffic lights to the operation of military bases to the electricity needed to power a toaster. All sources of energy have their benefits and drawbacks. Unfortunately, their various attributes make the transition even more complex.

Cost/Benefit Analysis of Nonrenewable Energy

The nonrenewable energy industry has generated significant revenue for businesses and governments. For instance, the energy sector generated approximately 4.5% of Australia's GDP in 2015 (15). In 2022, Denmark's crude oil and natural gas extraction industry had a turnover of 3,248.52 million euros (16). The revenue collected from fossil fuel funds several programs that benefit the economy and society in many ways, such as schools, infrastructure, and even healthcare. The economic growth generated by fossil fuels further contributes to countries worldwide' overreliance on nonrenewable energy. An immediate move away from non-renewable resources would have significant financial consequences, reducing the money governments and communities rely on to pay for infrastructure such as solar panels, wind, hydroelectric power, and primary energy storage systems.

More upfront investment is required, as these green technologies tend to have limited funding in the short term. These switches are expensive, and the requirement to maintain the financing of current programs and policies can quickly result in adverse outcomes if the green energy transition occurs too fast. In addition, the nonrenewable energy industry is responsible for many jobs. The number of jobs this industry supplies does not just derive from directly operating coal and oil mines. They also come from logistics, equipment management, or even construction. The most basic way nonrenewable energy is provided for countries is via its energy production. Compared to renewable energy, nonrenewables have high energy density and more extensive availability regardless of their adverse environmental effects (17).

However, nonrenewables also create enormous external costs from production. New research from Harvard University, in collaboration with the University of Birmingham, the University of Leicester, and University College London, found that more than 8 million people died in 2018 from fossil fuel pollution, significantly higher than previous research suggested—meaning that air pollution from burning fossil fuels like coal and diesel was responsible for about 1 in 5 deaths worldwide (18). The external costs significantly hurt both society and the economy, with fatalities, lost benefits from a larger workforce, and a significant strain on public healthcare services due to the effects of CO2, PM, and many other forms of pollution, furthering the need to switch to renewables at a high-risk faster pace.

Cost/Benefit Analysis of Renewables

Renewable energy sources, such as wind, solar, and hydroelectric power, are our best alternative to coal and oil production. Renewable energy benefits from relying on an unlimited source compared to the limited amount of fossil fuels we have left. Solar energy has the advantage of accessibility in any location since it does not rely on being in a particular place to run efficiently. On the other hand, nonrenewables rely on locations with high amounts of oil, coal, and natural gas. Wind farms have slightly more specifications on location due to wind patterns, but countries can still construct them in many places, including rural and developing areas. Because of the location specification and high up-front costs, many developing countries depend on energy imports from other countries due to difficulties implementing nonrenewable energy sources. However, with renewables as an alternative, developing areas can become more resilient and independent when specific issues and crises occur, allowing them to address situations faster without the help of other nations.

These green energy sources can also act as strong drivers of economic growth. With innovation and research expanding in several countries for the goal of sustainability, renewable energy has been increasingly attractive to investment, creating energy that is more cost-effective in the long run with lower operational costs and several subsidies that they receive. The path to green energy also fosters competition throughout the global market, helping other OECD countries to create renewable energy technologies that may initially have costs with more funding and investment from outside businesses and governments. Furthermore, unlike nonrenewable energy sources, green energy has minimal negative externalities through energy generation. When fossil fuels and oil industries generate energy, the high amounts of CO_2 and PM they release cause harm to local communities and businesses, negatively impacting the labor market and consumption factors of GDP with less money in the circular flow of the consumer-producer relationship through both rural and urban communities. Green energy does not produce these emissions through electricity generation and, therefore, has little to no negative impact on the economy via pollution throughout energy production.

Finally, the ultimate goal with renewable energy sources is to meet net zero by 2050 to effectively control global warming to 1.5 degrees Celsius and minimize human harm. Even though nonrenewables have this one significant consequence, we still need some form of energy to help sustain essential societal and economic functions, urging global forces to use other alternatives like green energy. The most significant benefit of green energy is the minimal pollution and deaths caused by renewable energy. These sources allow for environmental sustainability, producing little to no greenhouse gasses and particulate matter that harm global communities and ecosystems compared to the high pollution caused by nonrenewables. Thus, the change becomes essential to preserve enough energy to fuel entire nations more safely and cleanly without causing external harm.

With all the significant benefits of green energy and the pressing issue of climate change, many people would think this would be at the forefront of global efforts. Unfortunately, there are still several consequences to implementing renewable energy sources. First is the cost. Nonrenewable energy source extractions have already been placed worldwide, making it easier to create energy with the tools humanity already has access to. Renewable energy sources are safer for health. However, large solar panel fields, wind farms, and dams are still required to replace the few efficient fossil fuel energy sources within the same region, not to mention the high costs from energy storage and grid upgrades to manage intermittent power supply. These plans cost significant amounts of money that many developing countries and areas simply need to have after providing other essential services like healthcare and education. The United States alone requires 4.5 trillion dollars to transition to renewable energy completely (19). Another implementation issue regarding green energy is the land needed for implementation.

Developing areas may need help to afford the high costs of gaining enough land to implement green policies. Even if they could gather the funding necessary for construction, they would have to raze local ecosystems and forests to destroy enough land to instill solar fields and wind farms. Hydroelectric dams run the risk of disrupting local aquatic wildlife and causing severe displacement from native habitats, ultimately further harming an environment that renewable energy was supposed to have no impact on. Finally, the most significant harm is the minimal power generated to replace the big oil industries. Renewable energy sources like solar and wind have very low energy density compared to fossil fuel production and thus require significant amounts of revenue and money to fund policies that attempt to reduce fossil fuel production and enhance large-scale green energy production (17).

Both energy sources have attributes that benefit or harm society in different ways. However, due to the ultimate costs of global warming, policymakers must take the initiative to shift to renewables despite the obstacles. Otherwise, nations will continue to rely on fossil fuels and march toward the destruction of the Earth, or economies will collapse in the process of the green energy transition.

MATERIALS AND METHODS

This paper will analyze both the green policies and the energy sectors for each country to determine if green energy and the green transitions match our hypotheses that green energy may hurt GDP and vice versa for nonrenewable energy, as well as our hypotheses below for each policy we are analyzing in this paper. This paper utilizes Ordinary Least Squares (OLS) regression analysis and fixed effects to observe the relationship between green policy implementation functioning as a policy dummy and GDP growth as a dependent variable measured in % change in GDP. Several control variables are used to ensure greater accuracy. This analysis best captures their relationship, as most of the investment side of GDP has a hefty reliance on energy for essential functions, with similar reasons for net exports and minor forms of government spending.

Independent and Dependent Variables

This paper analyzes the most critical impact of a change in the energy industry with our dependent variable: the economy. To ensure the policies create neither short-term nor long-term economic harm, I will set the dependent variable for green policy impacts as GDP growth, measured in percent. GDP Growth directly correlates to whether the economy is growing or being harmed by external factors, with a positive coefficient showing growth and a negative coefficient displaying economic downturn, making it the best indicator of GDP. Collected from the World Bank, this data is measured by the change in the volume of its output or the real incomes of its residents. The 2008 United Nations System of National Accounts (2008 SNA) offers three plausible indicators for calculating growth: the volume of GDP, real gross domestic income, and real gross national income. The volume of GDP is the sum of value added, measured at constant prices, by households, government, and industries operating in the economy. GDP accounts for all domestic production, regardless of whether the income accrues to domestic or foreign institutions (20). Economic growth is a stronger indicator of economic prosperity as a positive or negative value directly correlates to a firm or weak economy, respectively, post-green policy establishment.

The independent variable of this analysis will be the amount of terajoules produced by each energy source in a particular country. This paper looks at the energy supply in a specific country and how utilizing energy consumption creates errors from energy imported from other countries rather than showing only the country's reliance on the energy industry. Energy supply in terajoules will directly present a country's energy utilization for essential functions, investment, government spending, net exports, and self-reliance on the energy source. In addition, this data was collected from the IEA, an organization with comprehensive data specifically focused on the energy sector for countries worldwide, providing the total energy supply for every energy source a country uses. Some countries' energy policies may place preference on different renewable energies based on current conditions. For instance, Sweden established the Network for Wind Power Act to promote further increases in wind energy (21). At the same time, the Netherlands' National Energy Agreement for Sustainable Growth aimed to transition to clean energy as a whole without focusing on specific energy sources.

Policy Dummy

A. Australia's Renewable Energy Target

This policy works to create Large-scale Generation Certificates (LGCs) and Small-scale Technology Certificates (STCs), reducing the immense cost of renewable energy production (22). This policy directly impacts wind, solar, and hydroelectric power, and the policy dummy will be equal to 1 from 2010-2020 and 0 otherwise. This policy may positively impact economic growth as decreased costs are the primary way renewable energy sources negatively impact the economy.

B. Brazil's Programme of Incentives for Alternative Electricity Sources (PROINFA) program

This policy aims to decrease economic costs for renewable energy production with additional funding and increase the number of job opportunities within the renewable energy sector (23). This policy directly affects all renewable energy, while the policy dummy will be set equal to 1 from 2002-2022 and 0 otherwise. This policy will have a minimal impact on economic growth as the increased employment from renewables could offset the job loss in decreased nonrenewable energy sources.

C. Canada's Ontario Feed-In Tariff Programme

This policy focuses on a fixed tariff for electricity produced and fed into the grid, with prices covering project costs and easy contract access to renewable energy farm creation (24). This policy directly affects all renewables, while the policy dummy will be set equal to 1 from 2009-2014, with the program ending in 2011 and a 3-year implementation lag. This policy will positively impact economic growth as these decreased costs allow companies to better maintain a large workforce and capital to increase productivity, along with the decreased negative externalities of pollution from nonrenewable energy.

D. Denmark's Energy Strategy 2050

This policy takes on a more dramatic approach to the energy transition, banning forms of oil production, more restricted building codes while funding R&D for renewable energy, and a tax system that goes easy on renewable energy systems compared to nonrenewables (25). This policy affects all energy sources except hydroelectric and heat energy sources. In contrast, the policy dummy will equal one from 2011-2022 as the initiative aims to work long-term to meet net zero by 2050. This paper hypothesizes that this policy will negatively impact the economy, as this aggressive action to continue the energy transition may result in an increase in unemployment from less nonrenewable energy and only funding renewable energy sources to compensate.

E. Netherlands' National Energy Agreement for Sustainable Growth

This policy takes a more nuanced approach, attempting to gain support from countries and organizations to help further the transition with additional funding and assistance (26). This policy directly affects all renewable energy, with the policy dummy set equal to 1 through 2013-2022 and 0 otherwise. This paper has chosen this policy to see if transitions' success lies in the ultimate collaboration with other countries. This policy will harm economic growth, as it only focuses on minor increases in job opportunities in the clean energy market, with little to compensate for the decreased use of nonrenewables and more unemployment in these sectors.

F. South Africa's Renewable Energy Independent Power Producer Programme (REIPPP)

This policy attempts to increase renewable energy's share within the energy sector through auctions to construct and supply large-scale renewable energy capacity. Purchase Power Agreements (PPAs) are guaranteed for around 20 years (27). This policy directly affects renewables from 2011 to 2018, as the auctions ended in 2015 with a 3-year implementation lag for employment and more capital. This policy will positively impact economic growth due to lower costs, more job opportunities, assistance for renewable energy construction, and fewer negative externalities due to less reliance on nonrenewable energy sources.

G. Sweden's Electricity Certificate System

This policy acts similarly to that of Australia, aiming to help minimize the costs of creating renewable energy to increase the production of such (28). This policy has already been shown to increase the share of renewable energy in the energy sector, yet it still needs to show its economic impact. This policy directly affects renewable energy, and the timeframe for this policy will be 2003-2022, given that the electrical certificates are given from 2003-2020 with an implementation lag to see more job opportunities. This paper hypothesizes that higher employment opportunities, cost minimization, the attraction of businesses to the renewable energy sector, and decreased negative externalities will cause this policy to have a positive impact on economic growth.

H. Uruguay's Decree 354 on the Promotion of Renewable Energies

This decree seeks to increase funding for renewable energy projects, about 5.5 million USD, for creating biofuel, biomass, solar, and wind energy sources through direct financing and auction systems (29). This policy directly affects the energy sources mentioned and will have a timeframe set to 2012-2022, as while the funding occurs from 2011-2015, the auctions continue into 2030. This policy will negatively impact GDP Growth as with actual structures and enforcement measures for this policy; the funding may lead to long-term economic benefits compared to harmful economic consequences stemming from unemployment and less investment with less nonrenewable energy sources.

Control Variables

Due to GDP Growth overseeing several branches outside the energy industry, control variables are required to help minimize that error with GDP Growth. The energy industry significantly impacts investment, net energy exports, and government spending from revenue from energy production. This leaves us two major GDP components to utilize as control variables: consumption and a minor part of government spending. Both data sets are collected from the World Bank to ensure this analysis effectively evaluates the energy industry's impact on GDP growth (30-31). Consumption Data was measured by household and government consumption of final goods and services. This study also chose to utilize government spending on education as another control variable, measured by the percentage of government expenditures. Both data sets help to eliminate errors and analyze a direct correlation between economic growth and the energy industry.

Equations

A. Impact of Renewable and Nonrenewable Energy Sources on GDP

First, this paper will analyze the impact of renewables and nonrenewables on the current energy system across all countries specified within the paper. This is first to analyze each energy type's impact on economic growth, determining if renewables have a positive or negative effect on GDP and similar for nonrenewables.

To examine this impact, this paper will analyze the following model for the data collected:

$$GDPg_{i,t} = a + b\,(Renewable\ Energy) + c\,(Nonrenewable\ Energy) + d\,(Consumption) + e\,(Government\ Spending\ on\ Education) + f\,(YearFE) + g\,(CountryFE)$$

B. Impact of Green Energy Policy on GDP

When constructing a regression model to examine the full energy impacts on nonrenewable and renewable GDP, this paper finds that using the policy dummy to represent the energy sector best identifies direct and indirect GDP impacts. Direct impacts present the green energy systems the policy directly supports or the nonrenewable energy the policy directly harms. Next, I will examine the indirect effects on GDP from energy sources not explicitly affected by the policy, as increases in renewable energy support increase their energy sector share. This change comes with disincentivized nonrenewables, generating less energy due to decreased public and government reliance on such sectors.

Using this idea, I constructed a model where the policy dummy replaces the entire energy sector to examine both impacts.

$$GDPg_{i,t} = a + b\,(Policy\ Dummy_{i,t}) + c\,(Consumption) + d\,(Government\ Spending\ on\ Education)$$

Finally, I will examine the coefficients of the policy dummy. If this analysis identifies $b > 0$, I can deem the policy successful as it has minimal or positive effects on GDP growth. Otherwise, the policy is unsuccessful as it damages economic growth and poses a risk to the local economy and the people who depend on it.

RESULTS AND DISCUSSION

This paper runs these models and equations through the program to identify which variables impact economic growth and observe the success of the Green Energy Policies and their potential to have minimal or positive impacts on economic growth.

Impact of Renewable and Nonrenewable Energy Sources on GDP

With the data given, renewable energy has a more probable positive impact on GDP overall across the countries analyzed. In contrast, nonrenewables have an adverse effect, with only nonrenewable energy's impact being statistically significant (Table 1). This result could be due to the renewable energy sector creating more jobs and production in the market, leading to positive

Table 1. Impacts Renewable and Nonrenewable Energy Sources on GDP

Variable	Coefficient (Standard Error)
Constant	6.215e-01(8.684e-01)
Renewable	2.760e-08(5.256e-07)
Nonrenewable	-7.611e-07(3.021e-07)*
Government Spending on Education (%GDP)	-3.078e+00(2.148e+00)
Consumption (%GDP)	7.483e-01(6.757e-02)***
Country Fixed Effects	Yes
Year Fixed Effects	Yes

R-Squared: **0.8182;** Adjusted R-Squared: **0.7698.**

economic growth and high costs, causing less investment in more successful firms and industries and decreasing economic growth. Furthermore, the negative impact of nonrenewable energy could stem from negative externalities, as pollution could significantly harm employment factors with a much smaller labor force. Consumption seems to significantly impact economic growth, which makes sense as it is the most significant GDP component. However, the standard error shows that it could positively or negatively impact economic growth. On the other hand, government spending on education has been shown to have a statistically significant negative impact on economic growth.

Impact of Green Energy Policy on GDP across Different Countries

A. Australia's Renewable Energy Target Policy

Observing both direct and indirect impacts on the economy from the Renewable Energy Policy, we see that the policy has a more probable positive coefficient, indicating a positive effect on economic growth potentially due to decreased costs from renewable energy, allowing for more capacity for employment and capital with less negative externalities (Table 2). The additional revenue from the certificates could have allowed companies and homeowners alike to use renewable energy without incurring extra costs. The chance for the coefficient to be negative stems from decreased use of nonrenewables, leading to less economic growth from these industries. As for the control variables, Consumption has a very significant positive impact on the Economy, while Government Spending on Education also has a positive effect. This could be the case as the decreases in nonrenewable energy due to less reliance on such energy could have decreased external costs, allowing for less pollution and more worker productivity, leading to increased GDP Growth combined with the certificates given to help incentivize renewable energy production.

B. Brazil's PROINFA programme

The Policy Dummy representing the entire Brazil Energy sector is more likely to impact GDP Growth negatively. The PROINFA program is similar to Australia's renewable energy target by providing subsidies to private industries for construction, yet does not emphasize it much compared to Australia's policy (Table 2). Brazil's policy added energy bills for consumers, which could have led to future resistance and inefficiencies with the program, thus creating a negative coefficient. This could also be due to decreased nonrenewables and less overreliance, leading to less nonrenewable production. Given that nonrenewable energy may be a key source of revenue for businesses and programs in Brazil, a decrease in its use could present a negative coefficient for the policy dummy. Consumption remains to have a very significant positive impact on the economy, while government spending also keeps the negative coefficient representing its economic costs.

C. Canada's Ontario Feed-in Tariff Programme

The Policy Dummy encompassing all energy sources in the country could have its positive

Table 2. Impact of Green Energy Policy on GDP in different countries

Variable	Australia	Brazil	Canada	Denmark	Netherlands	South Africa	Sweden	Uruguay
Constant	0.2840 (0.8808)	0.5147 (0.9855)	-1.2840 (1.0301)	-1.4431 (0.4740)	0.67943 (0.38398)	-0.29240 (0.29537)	0.2380 (1.1508)	1.3504 (0.6723)
Policy Dummy	0.2472 (0.4160)	-0.8281 (1.0624)	2.2197 (1.2774)	1.3813 (0.4931)	-0.02807 (0.48162)	0.18532 (0.33783)	0.6065 (1.0651)	-1.4109 (0.8638)
Government Spending on Education (%GDP)	2.0554 (5.1772)	-6.7795 (8.6964)	0.9834 (0.3096)	-0.1737 (3.3382)	-28.31525 (7.58745)	-5.20488 (4.08254)	-19.3656 (7.2629)	0.9322 (0.1003)
Consumption (%GDP)	0.7450 (0.2292)	0.9949 (0.1171)	1.4192 (11.3544)	1.4801 (0.1981)	0.85186 (0.16061)	0.91777 (0.06434)	0.8128 (0.2919)	-2.6081 (5.2018)
R-squared	**0.6965**	**0.8522**	**0.4907**	**0.8255**	**0.83**	**0.9273**	**0.6517**	**0.8921**
Adjusted R-squared	**0.6206**	**0.8206**	**0.3732**	**0.7947**	**0.8**	**0.9152**	**0.5902**	**0.8672**

coefficient as the increased job opportunities and decreased renewable energy costs may outweigh the negative externalities generated by nonrenewables, indicating the policy successfully impacts GDP (Table 2). Furthermore, similar to Australia's Renewable Energy Target, this policy creates a constant source of revenue for industries constructing renewable energy, helping to minimize costs and support capital necessary for construction. This shows that a subsidy-focused green energy policy has worked great in Australia and Canada. Consumption significantly impacts the economy, while Government Spending on Education has the same positive but less significant impact on GDP.

D. Denmark's Energy Strategy 2050

Denmark's Energy Strategy 2050 has a positive, statistically, and economically significant coefficient, different from this paper's initial hypothesis (Table 2). The direct decrease in nonrenewables could have led to the potential collapse of job markets and decreased investment from less revenue. However, the positive coefficient may stem from the intense funding to farm creation and R&D investment in the renewable energy sector, making these energy sources beneficial to Denmark's economy and outweighing the nonrenewable negative impact with decreased external costs. The additional money would allow for easier renewable energy creation and, like Australia and Denmark, show a stronger emphasis on funding, leading to a more positive coefficient. This indicates that these two energy sources have little impact on the local economy. Consumption and Government Spending have the same coefficient and significance as the previous model.

E. The Netherland's National Energy Agreement for Sustainable Growth

This policy in the Netherlands has a higher probability of harming GDP by including indirect impacts on other energy sectors, potentially due to the costs of pollution and negative impacts on the job market outweighing the support gained from the agreement (Table 2). Based on the data set, partnership with other organizations may not be enough to counter both the high costs of renewable energy and the costs of reducing nonrenewable energy alliance. The coefficient for Consumption makes sense with its positive significant impact on GDP; However, Government Spending on Education has a negative coefficient that is almost as significant. The negative coefficient may come from the decreased employment due to the negative externalities of businesses, such as pollution and health issues.

F. South Africa's Renewable Energy Independent Power Producer Programme (REIPPP)

The REIPPP policy's combined direct and indirect impacts on the energy sector have a positive coefficient, indicating a more probable positive economic impact (Table 2). This could be due to the auctions immensely reducing the economic costs, leading to more economic benefit than the costs from decreased reliance on nonrenewables. The coefficient is much smaller compared to the other successful subsidy projects. Still, as it is smaller and has less funding than the different policies, it could lead to the assumption that fewer subsidies create a less positive impact on GDP. Consumption significantly impacts GDP Growth, whereas Government Spending on Education hurts the economy, according to the model.

G. Sweden's Electricity Certificate System

Sweden's Policy still positively impacts GDP Growth with a higher probability, primarily due to the higher benefits than costs from the energy sector (Table 2). The Certificate System for Sweden mirrors the three subsidy programs of Australia, Canada, and Denmark, thus further justifying its positive coefficient for the green policy. Consumption remains to have a significant positive GDP impact, while Government Spending on Education has a significant negative economic impact.

H. Uruguay's Decree 354 on the Promotion of Renewable Energies

Considering the entirety of the energy sector and standard error, we observe that the policy dummy now has a more probable negative economic impact (Table 2). This could be due to the country's overreliance on nonrenewable energy, and the increase in renewable energy led to the decrease in nonrenewables, potentially creating adverse economic effects such as pollution, loss of revenue, and job loss. Contrary to the other subsidy programs, the financial support from this policy was not enough to positively impact GDP. Consumption and Government Spending on Education Variable still have extremely significant positive and negative effects on GDP Growth.

CONCLUSION

This paper finds green energy to have a more probable chance of positively impacting economic growth. In contrast, nonrenewable energy has a statistically significant negative coefficient, indicating its actual net effect on economic growth to be negative. Furthermore, by observing the green policies across these various countries and examining their direct and indirect economic impacts, this paper has concluded that the policies chosen from Canada and Denmark are successful due to their statistically significant positive coefficients indicating their positive economic impact. The green policies in Australia, South Africa, and Sweden have positive coefficients but are not statistically significant enough to claim they are truly successful. As for the green energy initiatives in Brazil, the Netherlands, and Uruguay, their negative economic impacts with indirect costs far outweigh the direct benefits created by such policies, Uruguay's policy being absolute with statistical significance, while the policies in Brazil and Netherlands are only more probable to be harmful to economic growth; thus, their particular policies are detrimental to economic growth and are deemed unsuccessful. Subsidy programs seem to have the most positive impact on GDP growth, with an immense amount of guaranteed decreased costs leading to a more significant positive effect on GDP Growth. The less statistically significant policies could derive from other events within the time ranges, such as the aftermath of the Great Recession, with year-fixed effects in 2009 and 2010 being very significant in our first model. Other than our initial hypothesis on Denmark, the models depicted in this study have confirmed all other hypotheses. However, even countries with high economic strength, such as the Netherlands, still have negative economic impacts despite the support from other organizations detailed within its National Energy Agreement for Sustainable Growth. Countries with smaller economies, such as South Africa, can maintain such extensive initiatives to help combat local pollution while still having a beneficial impact on economic growth rather than a harmful one. We must recognize that these models may still need fixing due to the variation from alternative investment and net exports that are far less concerned with the energy sector. Regardless, subsidy programs would have a more beneficial impact on the economies of OECD countries, as they create the highest amounts of economic growth across all the different policies analyzed in this study. Because these developing countries have little access to resources to manage the high costs of implementing green energy, they have to rely heavily on current energy sources, such as nonrenewables, which cause high pollutant costs and environmental harm within the country. These subsidy programs would help minimize this economic damage that could occur from their creation, and ultimately allow themto have greater economic growth in the long run with more cost-efficient energy production and more money circulating through their economy instead of being spent on the high costs pollution leaves in wake of the destruction it causes, pollution having the more harmful impact on OECD countries. As for more well-developed countries, subsidy programs would still be the most viable option as they would attract larger amounts of investment in the clean energy sector which would boost economic growth through both minimizing pollutant costs and maximizing innovation and R&D investment to propel economic growth forward, creating less reliance on nonrenewable energy to become 100% sustainable eventually. We must remember that although a damaged economy may harm people of all classes and groups, the long-term impacts of pollution and climate change may still pose a much more imminent threat than the job loss from green energy. Thus, in the future, countries must find that specific balance between reaching the net-zero goal to preserve and protect people's health worldwide and their need for a strong and growing economy to access necessities in the short term. With the determined successful energy initiatives examined in this paper, these policies would work best in countries that could best enforce the policy of their choice to maintain this balance and effectively fight pollution and global warming. Countries face severe health and economic costs without this slow and methodically planned transition. However, by keeping this balance, we ensure that people today can still access their basic needs while effectively bringing the world one step closer to beating global warming by meeting the UN's goal of zero emissions by the year 2050, ultimately meeting the needs of the present without compromising the needs of future generations, the essential definition of sustainability.

FUNDING SOURCES

No funding used.

DECLARATION OF INTERESTS

The author declares that there are no conflicts of interest regarding the publication of this article.

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