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POLITICAL FACTORS PREDICTING RENEWABLE ENERGY RESEARCH AND DEVELOPMENT LEVELS: MIXED RESULTS IN ORGANIZATION OF ECONOMIC COOPERATION AND DEVELOPMENT COUNTRIES FROM 1990-2000

By

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A THESIS

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Abstract

The goal of this paper is to determine why some Organization of Economic Cooperation and Development (OECD) countries allocate more public expenditure to research and development of renewable energy than others. This is attempted by offering a comparative analysis of the commitment to renewable energy by nineteen OECD governments from 1990-2000 using cross-sectional time series analysis. The main findings suggest that presidential democracies have higher levels of renewable energy R&D than parliamentary democracies and proportional legislative electoral systems have higher levels of renewable energy R&D than majoritarian electoral systems. However, these results should be interpreted cautiously as the impact of other political variables on renewable energy R&D, government composition and number of effective legislative parties, remains inconclusive.

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Introduction

Charles Galton Darwin, grandson of the renowned evolutionary theorist, anticipated significant changes in humanity's existence on earth in his book, *The Next Million Years* (1952). He called them "revolutions". Darwin expected that, "the fifth revolution will come when we have spent the stores of coal and oil that have been accumulating in the earth during hundreds of millions of years…it is obvious that there will be a great difference in ways of life" (154). Coal, oil, and natural gas are used in different combinations to generate infrastructure, power existing industry, heat private residences, as well as fuel millions of motor vehicles worldwide. High levels of global fossil fuel consumption would not be an issue if these fossil fuels were renewable, if there were infinite stores of the substances, or if we possessed technology to manufacture them ourselves. Unfortunately, none of the above appears to be true. This has the potential to cause significant problems, as almost every aspect of modern life requires energy. Scholars, policymakers, and nearly all citizens are in agreement that stores of these natural resources on earth are finite. The question is not how long will our fossil fuels last, but where do we get energy once the fossil fuels are gone. In particular, why do some Organization of Economic Cooperation and Development (OECD) countries allocate more public expenditure to research and development of renewable energy than others?

Energy sustainability is part of a much larger and more complex discussion of global environmental sustainability. Although public attention on environmental sustainability has recently increased, the existence of historical environmental movements shows that sustainability is not a completely new idea. Arthur Mol describes three waves of environmental reform in his aptly titled text, *Globalization and Environmental Reform* (2001). According to Mol, the first wave of environmental concern began in the early 1900s with a focus on conserving particular areas of land and protecting specific endangered species. Results of the first wave of environmentalism are the national parks, nature reserves such as the Arctic National Wildlife Refuge in Alaska, and habitats to stabilize low population levels. Though altruistic in nature, first wave reforms did very little to curb widespread environmental degradation. The larger issue of sustainable human existence on earth was instead covered with a small band-aid.

Over a half-century later, environmental watchdogs realized shortcomings of the first wave reforms. A second wave of environmental reforms emerged in the late 1960s and early 1970s, aiming to engrain environmentally friendly discourse into central institutions of society (Mol, 2001). National environmental agencies were established in most industrialized nation-states, concrete laws protecting the environment from waste appeared, and non-governmental organizations (NGOs) developed as second wave environmentalism experienced success (Mol, 2001, 49). Although laws and organizations were created to protect the environment during second wave reforms, the movement's desire to limit economic production and growth were met with resistance. Activists advocating theories of deindustrialization found themselves unable to overcome business opposition to such actions. It seems business preference for profits in the present over amorphous benefits in the future created a wall over which the second wave environmental movement could not climb.

The third wave of environmentalism began in the late 1980s, shifting efforts to sustainable economic development and theories of ecological modernization (Mol, 2001). Increased production efficiency and decreased environmental damage became the focus of these environmental reforms (Mol & Sonnenfeld, 2000). Instead of attempting to limit economic growth, ecological modernization theories proposed environmentalism that could coexist with a capitalist system of production. For example, Grossman & Krueger's (1995) work acknowledges that previous economic development has contributed to environmental problems, but contends further economic development may be able to solve these same problems. Mol (2001) claims solutions are not far off either; the past quarter-century has witnessed advancements in the transformation of modern industry (53). Some scholars such as York, Rosa, and Dietz (2003), however, are not optimistic that the current trend of economic modernization and growth can generate environmental sustainability for the future.

Debate between political scientists, economists, and sociologists has made clear that the pursuit of environmental sustainability has reached an important juncture. As energy sources for the 21st century become one of the principal topic areas in global policy discourse, a shift in the conversation from conservation and efficiency efforts toward the development of renewable energy sources may prove useful.

This study hopes to aid such a transformation in the discussion, but first must examine the efforts of other scholars. Subsequent sections will address theories and hypotheses surrounding the topic as well as this particular study's methodology. Results and analysis will follow, concluding with reflections on my findings and their implications for existing research.

Review of Relevant Literature

In reviewing the literature, one set of studies looks at renewable energy without comparative analysis; another set of studies offers comparative analysis of governmental environmentalism without looking specifically at renewable energy. The goal is to eventually bridge these two strands of the literature by offering a comparative analysis of the commitment to renewable energy by different governments. Before doing that, however, I need to review these two strands just mentioned.

Renewable Energy Technologies and Contextual Studies

One group of studies on renewable energy focuses on specific technologies that could be further researched and developed. These studies examine the 'hard science' side of renewable alternatives, seeking to determine which alternative should be given research and development priority in specific countries. Solar, bioenergy, wind, geothermal, ocean, and hydropower alternatives[1] have emerged as the list of leading renewable energy sources (Hepbasli, 2008; Joselin Herbert et al., 2007; Thirugnanasambandam, et al., 2010; Marchetti et al., 2007). Priority for research and development money is often based on combination of a country's natural resource assets (i.e. fast flowing rivers or strong winds for hydropower or wind power, respectively), economic competitiveness of the technology, and likelihood of research breakthrough.

[1] For further research on specific renewable energy technologies, I direct you to the International Energy Agency (IEA) website on international technology agreements. http://www.iea.org/techno/technologies/renew.asp.

Total R&D expenditure for renewable energy in IEA countries totaled about $1 billion in 2004 (Doornbosch and Upton, 2006). Solar, biofuels, and wind energy received the bulk of that R&D money, garnering $500 million, $261 million, and $122 million, respectively (Doornbosch and Upton, 2006).

Within the larger body of literature on potential renewable energy technologies is a subgroup that focuses on regional or country-specific contextual situations. A main region of interest throughout the literature is the European Union, due to the number of countries in relatively close geographic, social, and economic proximity. Segers (2008) research evaluates a proposed EU directive with binding targets for renewable energy production and consumption, promoting a method that accounts for differences in primary energy measurement between conventional and renewable sources. Accounting for these differences in measurement is important to avoid enacting policies that are inefficient at reaching the proposed directive's goals: saving conventional fuel and reducing carbon dioxide emissions. Similarly, Fouquet and Johansson's (2008) work on the EU compares tradable green certificates and feed-in tariffs as support mechanisms for renewable energy targets, finding feed-in tariffs to be more effective at lowering investor risks, raising incentives for innovation, and generating renewable energy. These support mechanisms are used to lessen the economic burden of renewable energy targets on a country until the market stabilizes imbalances of supply and demand.

Other contextual studies examine the development of particular renewable energy policy in specific countries. Breukers and Wolsink (2007), for example, research how institutional conditions affected policy for wind power in the Netherlands, finding that centralized policy-making and the underestimating of local support has slowed wind power development and actually *increased* resistance to such projects. Toke (2005) also cites local support as an important influence on wind power success, proposing the perception of economic benefit is a critical determinant for local policy support in England. Langniß et al. (2008) hope to improve the German Renewable Energy Act by providing more appropriate incentives and flexibility to the promotion mechanism and the compensation scheme without jeopardizing fast deployment of renewable energy technologies. Looking toward the future of renewable energy, Yüksel's (2010) analysis suggests hydropower energy production in Turkey could provide 33-46% of the country's electricity demand in the next decade. These case studies provide interesting research in contextual situations, but do not seek to explain variation in renewable energy policy by comparing across countries.

Factors Predicting Governmental Environmentalism

Economists Grossman and Krueger (1995) found a relationship between per capita income and environmental degradation in the shape of an inverted-U, which became known as the Environmental Kuznets Curve[2] (EKC). EKC[3] theory proposes that in industrializing nations with low levels of per capita income, environmental quality deteriorates as per capita income increases. Environmental quality is a luxury good during initial stages of economic development. When per capita income reaches a threshold level, however, the environment becomes a normal good and further economic growth may bring about improved quality. Empirical evidence supports the EKC's inverted-U relationship between per capita income and environmental degradation for

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[2] This name originated from work by economist Simon Kuznets (1955), who reported an inverted-U shaped curve relationship between economic growth and income inequality.
[3] See Stern (2004) for a thorough review of the environmental Kuznets curve literature.

some pollutants (Hettige et al., 1992; Selden and Song, 1994; Shafik, 1994; Holtz-Eakin and Selden, 1995). However, some studies heed caution regarding the interpretation of these claims. Arrow et al. (1995) concede that EKC theory has been shown to apply to a select set of pollutants, but take issue with some economists' extension of the theory to environmental quality in general. Furthermore, Stern, Common, and Barbier (1996) contend EKC theory relies on the assumption that world per capita income is normally distributed, whereas in reality the median income is far below the mean income. Violating this assumption creates problems estimating the parameters of an EKC for Stern, Common, and Barbier (1996).

Regime type also holds a place within literature on environmental quality. Since environmental quality is one type of public good, theories explaining the provision of public goods in general are valuable to this research. Several scholars argue democratic regimes provide more public goods than non-democratic regimes, including environmental quality (Olson, 1993; McGuire and Olson, 1996; Lake and Baum, 2001; Deacon, 2003). The resulting logic is as follows: since environmental quality is a public good; and, democracy provides more public goods than authoritarian forms of government; therefore, democracy improves environmental quality more than non-democracies.

Bueno de Mesquita et al. (2003) advance classification of regimes as democratic or autocratic beyond using the competitiveness of political participation as the primary measure. They claim a country's institutional design influences the selection of leaders and their incentives to provide public goods. Bueno de Mesquita et al. (2003) develop a model where the institutional features of the selectorate and the winning coalition determine whether the government provides private or public goods. In their model, the selectorate is the group of people who can affect the choice of and receive benefits for *selecting* leaders. A subgroup of the selectorate, members of the winning coalition receive economic benefits or other special privileges for ensuring the leaders maintain office. Autocratic regimes ruled by a small number of elites characteristically use available resources to redistribute income from their populations toward themselves and the winning coalition in the form of private goods. Therefore, little incentive exists in autocratic political systems to provide public goods such as environmental quality.

Empirical research in the literature has primarily focused on different measures of environmental degradation. In the past three decades alone, over thirty studies have been conduced using different environmental indicators to determine if political factors contribute to better environmental performance.[4] In one of the earliest studies on the subject, Congleton (1992) suggests liberal democracies are more willing to regulate pollution than less liberal regimes. The study uses empirical cross-national analysis of pollutant levels and government willingness to take part in international environmental conventions, finding support for political institutions as determinants of environmental regulation.

Further research has supported a positive correlation between democratic institutions and improved environmental quality by measuring pollutant levels. Crepaz (1995) asserts a correlation between corporatist institutions and lower levels of carbon dioxide, sulfur oxide, nitrogen oxide and particulate matter. In addition, Jahn (1998) and Scruggs (1999, 2001) find neo-corporatist institutions significantly improve

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[4] Consult Scruggs (2009) for a complete list of these studies. Some are cited throughout this paper, but not the complete list.

environmental performance versus countries with pluralist systems. Neo-corporatist institutions feature consensual and encompassing forms of interest group representation, increasing the provision of public goods by overcoming collective action problems that often plague environmental sustainability efforts. By contrast, pluralist systems are characterized by a more limited policy focus from government and competitive interest representation. Interest groups must compete with each other to build member size and strength, both of which are needed to influence policy.

Similarly, Li and Reuveny (2006) positively correlate democracy (Polity IV data) with lower carbon dioxide, nitrogen-oxide, water pollution, land degradation, and deforestation rates. Reporting a positive effect from the degree of democracy (Bueno de Mesquita et al.'s (2003) winning coalition over the selectorate variable) on air quality, Bernauer and Koubi (2009) conclude further that a presidential system produces better air quality than do mixed or parliamentary systems.

However, not all empirical research studies agree that democracy is beneficial to the environment. Midlarsky (1998) claims special interest groups have a disproportionate influence on policymaking in democracies. This implies democracies may under provide public goods such as environmental quality if strong special interest groups are in opposition. Empirically, Midlarsky (1998) reports democracy having an increasing effect on carbon dioxide levels, soil erosion by water, and deforestation rates. Barrett and Graddy (2000) find mixed results, reporting increases in political and civil freedoms (Freedom House indices) decrease sulfur dioxide, smoke, and particulate matter measures of air pollution. Pollutants in the water supply, however, remain unaffected by changes to political or civil freedoms in Barrett and Graddy's (2000) study.

Results indicating no statistically significant correlation between corporatist democratic structures and emissions levels have been reported more recently by Neumayer (2003), Battig and Bernauer (2009), and Scruggs (2009). While these reports of an ambiguous relationship do not indicate democratic institutions are bad for the environment, touting democracy as the cure for environmental problems should be done with caution.

Any and all research on this important topic is certainly beneficial, but simply isolating different pollutant levels as dependent variables makes meaningful generalizations about the impact of political factors elusive. A major limitation of current research is analyzing democratic institutions effect on *individual* pollutants, preventing analysis across multiple dimensions of environmental performance at the same time (Scruggs, 2009). Imagine Country X has democratic institutions, low deforestation rates, but high water pollution, sulfur dioxide and carbon dioxide levels. In this case, measuring the effect of democratic institutions on deforestation rates alone may lead a researcher to conclude that democratic institutions improve environmental quality. The omission of water and air pollutant levels from this study is clearly important. No study can be reasonably expected to include every cause of environmental degradation or measure every pollutant level. A more nuanced agenda is therefore needed to further environmental research.

Poloni-Staudinger's (2008) study helps to reframe the debate, advocating that drawing conclusions between democratic regimes and environmental policy enactment is more complex than some studies assume—the nature of policy issues, types of institutions, and veto players in the system are also important. Although her study produces inconclusive results, Poloni-Staudinger's (2008) research is a valuable addition to the literature because it shifts the discussion away from the impact of democracy on *pollutant levels* to the impact of democracy on *environmental policymaking*. This is especially important to avoid an entirely historical-oriented research agenda—as measuring pollutant levels forces researchers to look backward on pollution that has already occurred. Shifting measurement to environmental policymaking still allows empirical analysis, but also offers the ability to explain, predict and prescribe environmental policy changes for the future.

Adding to Literature on Governmental Environmentalism

Throughout the literature, most empirical studies have focused on the linkages between per capita income or democracy and environmental performance. Little has been written about the impact of income or democracy on research and technology development. However, Komen et al.'s (1997) research exists as an outlier, suggesting public expenditure for R&D toward environmental improvements increases with national income. They report a positive effect of per capita income on R&D for environmental protection generally, but do not include renewable energy R&D in particular. To my knowledge, no study analyzes national R&D budgets of renewable energy as a dependent variable.

Some research investigates the effect of political determinants of environmental performance and policymaking (Congleton, 1992; Crepaz, 1995; Scruggs, 1999, 2001; Poloni-Staudinger, 2008; and Bernauer and Kolbi, 2009). Other research examines economic determinants of public expenditure on environmental protection R&D (Komen et al., 1997). To the extent that levels of R&D have been in the dependent variable, the independent variables have been economic, not political in nature. This research attempts to bridge the gap by linking causal political factors with public renewable energy R&D budgets. Political determinants of renewable energy R&D budgets are the primary focus of this study—but the influence of economic and social factors will also be incorporated.

The next section discusses theoretical developments of linkages between democratic institutions and environmental quality to tease out testable hypotheses. Following this theoretical exploration will be an in-depth analysis of the variables tested and research design for this paper.

Theory and Hypotheses

To develop testable hypotheses about the impact of political institutions on public renewable energy R&D intensity, this paper draws from theories on the provision of public goods and democratic classification. In addition, ecological modernization theory supports the inclusion of some economic and socio-cultural control variables to the model.

Providing Public Goods

Theories on the provision of public goods in democracies are valuable to generate hypotheses about the influence of political institutions on public renewable energy R&D intensity. This paper requires the acceptance of two assumptions regarding public goods and environmental quality. The first assumption is straightforward and should encounter little opposition—environmental quality is a public good. In economic terms, public goods are non-rivalry and non-excludable. For this paper non-rivalry means that consumption of environmental quality by one individual does not prevent consumption by others, while non-excludability means that no one can be excluded from enjoying the level of environmental quality in an area. The second assumption, however, is less obvious—public investment in renewable energy R&D is made to improve environmental quality. This author believes the second assumption to be sound, as a research breakthrough and subsequent deployment of renewable energy technology would improve environmental quality. Some may contend that breakthrough technology may not be made available for consumption without compensation, much like a private good. While this may be true, the technology would be a private good but the resulting improvement in environmental quality would still be a public good.

Within the literature on the effects of regime type and the provision of public goods, two studies are at odds with each other. Persson et al. (2000) contend legislative cohesion (disciplined voting by coalition members) in parliamentary systems creates policies to please the majority of voters. They claim that the increased provision of public goods, such as environmental quality, is one strategy employed to please the majority. Alternatively, Bueno de Mesquita et al.'s (2003) research on selectorate theory argues that different forms of democracy produce winning coalitions that vary substantially in size. According to their research, presidential systems require a larger winning coalition than parliamentary systems, and therefore provide more public goods. This study's first hypothesis builds on Bueno de Mesquita, Smith, Siverson, and Morrow.

H_1: Presidential systems have higher levels of public renewable energy R&D intensity than parliamentary or mixed systems.

Classifying Democracies by Institutions

Other comparative political theory seeks to classify democracies based on different institutional configurations found in countries around the world. Arend Lijphart (1984, 1999) has been a leader in this strand of research, classifying democracies as one of two types—consensual or majoritarian—suggesting consensual democracies demonstrate higher levels of governmental environmentalism than majoritarian democracies. Since this study will primarily be testing individual political traits of Lijphart's consensual and majoritarian democracies on public renewable energy R&D intensity, a simple dichotomous measure of majoritarian versus consensual democracy may also prove useful. It is worth noting here that Lijphart's majoritarian and consensual classifications are pure types of democracy that very few countries approach in reality. Despite this reality, this hypothesis still deserves inclusion as an umbrella measure of Lijphart's theory.

H_2: Consensual democracies have higher levels of public renewable energy R&D intensity than majoritarian democracies.

Lijphart identifies ten traits that characterize each type of democracy, three of which are appropriate to include in this study. The first variable of Lijphart's classification utilized in this research is a country's legislative electoral system.

Consensus democracies are typified by proportional representation while majoritarian democracies exhibit disproportionality of elections. Electoral disproportionality (i.e. majoritarian) refers to plurality, absolute, or qualified majority requirements. Lijphart asserts higher governmental environmentalism in consensual democracies; Scruggs (1999) agrees with regard to the effect of the legislative electoral system. Proportional representation encourages the representation of diffuse benefits, allowing smaller parties to gain policy influence by compelling larger parties to accommodate those interests through the process of party competition (Scruggs, 1999, 9f).

H_3: Proportional legislative electoral systems have higher levels of public renewable energy R&D intensity than mixed or majoritarian systems.

Another of Lijphart's democratic traits used as an independent variable in this study is a government's cabinet composition. Lijphart suggests majority cabinets composed of single party run majoritarian governments, whereas consensual governments tend to have broad coalition governments. This paper will hypothesize higher levels of R&D funding is found in consensual democracies and their proportional electoral systems.

H_4: Surplus coalition governments have higher levels of public renewable energy R&D intensity than single party majority governments.

The last of Lijphart's traits used in this research as a determinant variable is the type of party system. Two dominant parties characterize majoritarian democratic systems, while consensual democracy fosters a multiparty system. This paper will continue to hypothesize that consensual democracies, and therefore multiparty systems, exhibit higher governmental environmentalism.

H_5: As the number of effective political parties increases, public renewable energy R&D intensity will also increase.

An extension from the effective number of political parties is the representation of diffuse interests, leading us to the final political variable. In a two-party system, the parties focus on the core issues to win election—taxes, national security, healthcare, etc. Environmental quality is not generally considered a core interest. Instead, environmental quality exists as a periphery interest championed by the green party. Bernauer and Kolbi (2009) report a statistically significant impact of the strength of the green party on concentrations of sulfur dioxide. Following this logic, this study expects a stronger green party to be related to higher levels of renewable energy R&D intensity.

H_6: As the number of seats in a government's legislature held by green party members increases, public investment in renewable energy R&D will also increase.

Control Variables

Although the political determinants of public renewable energy R&D intensity are the main focus of this paper, a number of economic and socio-cultural variables need to be included as controls. The most prominent of these is economic output per capita, which Komen et al. (1997) find statistically related to R&D for environmental protection in general. Furthermore, Deacon (2003) finds that per capita income is strongly related to the provision of public goods in democracies. In accordance with both, this study will hypothesize a positive relationship between per capita GDP and renewable energy R&D.

H_7: As the level of GDP per capita increases, public renewable energy R&D intensity will also increase.

As was shown earlier, much of the current literature uses pollutant levels in their research (Congleton, 1992; Crepaz, 1995; Neumayer, 2003; Li and Reuveny, 2006; Scruggs, 2009). Although pollutant levels are not directly related to the level of funding appropriated for renewable energy R&D, a common underlying logic does exist between the two. The best concept to explain this linkage is governmental environmentalism. A government that actively seeks to protect the environment is more likely to enact policies to regulate pollutant emission levels than a government where environmentalism is not *a* primary concern. Similarly, high levels of governmental environmentalism may result in more renewable energy R&D than low level of governmental environmentalism. From this logic, I will hypothesize pollutant levels are inversely related to public renewable R&D intensity.

H_8: As carbon dioxide emissions decrease, public renewable R&D intensity will increase.

Logically related to the level of pollutant emissions is energy use. Since available technology does not provide perfect energy efficiency, pollution is a resulting by-product. I expect these variables to be the most closely correlated. The level of energy use has a more intriguing role in this research than simply correlating with carbon dioxide emissions. I expect the level of energy use to have an independent effect on investment of renewable energy than carbon dioxide emissions. As a country's need for energy increases, finding a renewable source of energy would seem appealing. Therefore, increased investment in renewable energy R&D would be the rational policy response.

H_9: As energy use increases, public renewable R&D intensity will also increase.

The tenth hypothesis addresses the distribution of a country's population. Poloni-Studinger (2008) cites research establishing a link between population density and environmental effectiveness. This study will put forward a similar positive relationship between urbanization density and renewable energy R&D.

H_{10}: As the rate of urbanization increases, public renewable R&D intensity will also increase.

The IEA source that provides data on renewable energy R&D also provides data on nuclear energy R&D[5]. Based on assumptions concerning the zero-sum nature of the budgetary process, my final hypothesis in this study is that renewable energy R&D and

[5] Nuclear energy is not considered the same category as renewable energy, a distinction explained further in the section on data and research methodology.

nuclear energy R&D are in competition for the same funds and therefore have an inverse relationship.

H_{11}: As levels of nuclear energy R&D increase, public renewable R&D intensity will decrease.

Data and Research Methodology

This study seeks to fill a void in the literature explaining why public renewable energy R&D intensity is larger in some countries than in others. Public renewable energy R&D intensity is measured using a country's national renewable energy R&D budget as a percentage of its GDP. Doornbosch and Upton (2006) cite industrial R&D intensity as an oft-used indicator for innovation in economic analysis. R&D intensity = (R&D expenditure / industry production total), thereby allowing comparison with R&D intensity in other parts of the economy.

I create my dependent measure based on the above equation with slight alterations: public renewable energy R&D intensity = (public renewable R&D expenditure / public production total). Public R&D expenditure data come from the International Energy Agency (2009) as millions of constant U.S. dollars (USD). I multiply these values by one million, converting them to constant 2008 U.S. dollars. Since this study expands industry R&D expenditure to public R&D expenditure, the industry production denominator must also be altered to reflect public production total.

A country's public production total is measured using gross domestic product (GDP). These data points come from The World Bank's (2010) World Development

Indicators database measured in constant 2000 USD. I use the U.S. consumer price index (CPI), base year 2005, provided by The World Bank[6] (2010) to convert GDP values to constant 2008 USD. This is needed for consistency with public R&D expenditure in the numerator of the equation. The difference between 2008 and 2000 prices is 23.22 (The World Bank, 2010). That value is used to create the dependent variable denominator: GDP in constant 2008 USD = (GDP in constant 2000 USD)*(1.2322). The importance of GDP in the denominator is to control for differences in economy size. Without this control, countries with larger economies may distort the actual level of renewable energy R&D. My dependent measure calculates renewable energy R&D over GDP, yielding the percentage of a country's GDP appropriated for renewable energy R&D, which I refer to as renewable energy R&D intensity. Percentage of GDP allocated for renewable energy R&D is extremely low, ranging from $3.3772*e^{-6}$ percent in 1997 France to 0.000221268 percent in 1993 Denmark.

This measure of R&D investment is optimal because budget allocation and appropriation is a direct measure of issue priority within a government. For application in the real world, this research views levels of R&D expenditure as reliable measures of innovative capacity (Doornbosch and Upton, 2006, 31). Margolis and Kammen (1999) and Guellec and Van Pottelsberghe de la Potterie (2001) support this assumption with empirical econometric studies. These studies find statistically significant correlations between R&D intensity and technological development, measured by number of related patents and total factor productivity, respectively.

[6] Constant USD are preferred to other calculations such as purchasing power parity (PPP) because the measurement avoids problems of inflation from year to year in time-series analysis.

Although this study is not concerned with specific renewable energy alternatives, the classification of 'renewable energy' itself is very important. For the purposes of this paper, 'renewable energy' refers to solar, bioenergy, wind, geothermal, ocean, and hydropower alternatives. Nuclear fission and fusion are considered their own category of alternative energy, as are hydrogen and fuel cells research (IEA, 2009). Therefore, neither nuclear fission and fusion nor hydrogen and fuel cells R&D are not included in the dependent variable.

Table 1: Summary Statistics

Variable	Hypothesis #	Mean	Minimum	Maximum	Standard Deviation
R&D Renewable Energy (USD)	---	$4.95*e^{7}$	968000	$3.63*e^{8}$	$6.64*e^{7}$
GDP (USD)	---	$1.46*e^{12}$	$1.08*e^{11}$	$1.20*e^{13}$	$2.52*e^{12}$
DV	---	.000065	$3.38*e^{-6}$	.0002213	.0000557
Regime Type	H_1	1.392473	1	3	.6910605
Democracy Type	H_2	.9139785	0	1	.2811526
Legislative Electoral System Type	H_3	1.580645	0	3	1.170101
Government Type	H_4	1.897849	0	4	1.56146
Number of Effective Legislative Parties	H_5	3.728012	1.91	9.05	1.491204
Green Party Strength	H_6	1.987812	0	7.65	2.591554
Per Capita GDP (USD)	H_7	27824.53	10820.5	46173.46	8906.25
Carbon Dioxide Emissions (metric tons per capita)	H_8	9.810061	4.752841	20.33352	3.849995
Energy Use (kg oil equivalent per capita)	H_9	4462.718	1705.687	8162.706	1643.169
Urbanization (%)	H_{10}	73.82774	48.54	97.04	10.09655
R&D Nuclear Energy (USD)	H_{11}	$3.04*e^{8}$	41000	$2.98*e^{9}$	$6.58*e^{8}$

Independent Political Variables

The first hypothesis in this study posits that presidential systems have higher levels of public renewable energy R&D intensity than parliamentary or mixed systems. This hypothesis draws on selectorate theory from Bueno de Mesquita et al. (2003) on the provision of public goods. Measurement of regime type is ordinal, ranging from 0 to 3. Matt Golder's (2005) database, Democratic Electoral Systems Around the World, 1946-2000, provides these data points. No recoding of Golder's variable [*institution*] is necessary; 0 = dictatorship, 1 = parliamentary democracy, 2 = mixed democracy, 3 = presidential democracy. Summary statistics in Table 1 report a minimum value of 1, indicating there are no cases of dictatorships in this study. The mean value is 1.392473, meaning this study has more cases of parliamentary democracy than presidential democracy.

The second hypothesis uses a dichotomous measure of the type of democracy present in a country. Lijphart (1984, 1999) theoretically and empirically develops two types of democracies, majoritarian and consensual, categorized using ten different traits. This dichotomous measure of democracy type is the aggregation of all ten traits. In accordance with Lijphart, this study hypothesizes consensual democracies have higher levels of public renewable energy R&D intensity than majoritarian democracies. I expect this political variable to be the weakest predictor of renewable energy R&D intensity because pure forms of democracy represented by the dichotomous measure are rare in reality. Nevertheless, this variable is important to include in the model. Golder (2005) supplies these data points [*majoritarian*]; consensual democracy = 0, majoritarian democracy = 1. I recode the data, flipping the values so majoritarian democracy = 0, consensual democracy = 1. I do this so a positive coefficient indicates higher renewable energy R&D intensity, and to avoid confusion when interpreting results tables. Table 1 lists a mean value of .9139785, indicating this study includes many more cases of consensual democracy than majoritarian democracy.

The third hypothesis shifts to one of Lijphart's (1984, 1999) political traits used to classify democracies. Differences in legislative electoral systems between countries are captured by this ordinal variable. I hypothesize proportional legislative electoral systems have higher levels of public renewable energy R&D intensity than other electoral systems. Golder (2005) provides these data points in variable [*elecsystem_type*]; 1 = majoritarian, 2 = proportional, 3 = multi-tier, 4 = mixed systems. I recode this categorical variable into an ordinal form where 0 = majoritarian, 1 = mixed, 2 = multi-tier, 3 = proportional.

Majoritarian electoral systems include plurality, absolute and qualified majority requirements, as well as alternative vote methods in Australia and the single non-transferable vote (SNTV) in Japan. On a scale with majoritarian and proportional electoral systems at the extremes, mixed and multi-tier systems fall in the middle. Mixed systems use majoritarian and proportional rules, most of which have more than one tier. Multi-tier systems use a single electoral formula (majoritarian or proportional) in multiple electoral tiers. Since only Papua New Guinea and Mauritius use majoritarian multi-tier systems, I code multi-tier systems closer to proportional electoral systems than mixed electoral systems. Proportional (PR) electoral design include quota systems (allocation of remainders), highest average systems, and single transferable vote methods. Table 1 reports a mean value of 1.580645, indicating this study includes relatively even numbers of each legislative electoral system—leaning slightly on the side of proportional systems.

Admittedly, institutional measures such as regime type and legislative electoral rules do not vary greatly from year to year, as institutions by definition are more static than the governments that hold office for a period of time. However, some institutions do change during the time-series this research covers, offering interesting cases for further study as well as increased variation in the data. 1994 marks a shift in Italy from a multi-tier to a mixed electoral system. From 1995 and 1996, both Japan and New Zealand altered their majoritarian electoral system to mixed forms.

A fourth hypothesis in this research addresses the type of cabinet in the government holding office. It posits higher levels of public renewable energy R&D intensity are found in surplus coalitions than in single party majority governments. This hypothesis is derived from Lijphart's (1984, 1999) first dimension on the type of executive. These data points come from the Comparative Political Data Set I (CPDSI), 1960-2007 (Armingeon et al., 2009) in variable [*gov_type*]; 1 = single party majority, 2 = minimal winning coalition, 3 = surplus coalition, 4 = single party minority, 5 = multi party minority, 6 = temporary government. I recode this categorical variable into an ordinal form consistent with Lijphart's classification of majoritarian and consensual democracies: 0 = single party majority, 1 = single party minority, 2 = multi party minority, 3 = minimal winning coalition, 4 = surplus coalition. Cases of temporary government are removed from the data because temporary government's do not set national budgets and because the number of lost cases is minimal. Table 1 cites a mean value of 1.897849, representing relatively normal distribution in the variable.

A fifth hypothesis contends that as the number of effective political parties increases, public renewable energy R&D intensity will also increase. Lijphart (1984, 1999) suggests majoritarian democracies are characterized by a two-party system, while consensual democracies are typified by a multi party system. Data points on the effective number of parliamentary parties come from the Golder (2005) database, variable [*enpp1*], on a continuous scale. Table 1 expresses a range from 1.91 to 9.05 effective number of parliamentary parties. The mean value of 3.728012 indicates Belgium is an outlier, as it never has fewer than eight effective parliamentary parties, while only Italy in 1994 and 1995 has at least seven.

The sixth hypothesis extends from the effective number of parliamentary parties, hypothesizing that as the number of seats in a government's legislature held by green party members increases, public investment in renewable energy R&D will also increase. These data points come from Armingeon et al. (2009) in the CPDSI, variable [*sgreen1*], on a continuous scale. The values measure the percentage of seats held by green parties in national legislatures. Table 1 shows a range from 0 to 7.65 with a mean value of 1.987812, implying the share of legislative seats held by green parties is often very low.

Independent Control Variables

The seventh hypothesis brings us to the control variables in the model, proposing that as the level of per capita GDP increases, public renewable energy R&D intensity will also increase. These data points come from The World Bank's (2010) WDI database in 2000 constant USD. As with the dependent variable, the US CPI is used to convert 2000 constant USD into 2008 constant USD. I then log these values to reflect a more normal distribution of the data to enhance the statistical modeling. Per capita GDP measured in constant 2008 USD has a range from 10820.5 to 46173.46 and a mean value of 27824.53. These values indicate a distribution very close to normal.

An eighth hypothesis uses previous research (Congleton, 1992; Crepaz, 1995) to hypothesize an inverse relationship between carbon dioxide emissions and public renewable energy R&D intensity. These data points come from The World Bank's (2010) WDI database, measured in metric tons per capita. I log these values in the statistical modeling, however Table 1 reports real figures that are more easily understood. Carbon dioxide emissions range from 4.752841 to 20.33352, with a mean value of 9.810061 indicating close to normal distribution.

Hypothesis nine suggests as energy use increases, public renewable R&D intensity will also increase. This may be the case if a government fears its energy demand is outgrowing supply and renewable energy becomes an economic necessity. Data points for energy use come from The World Bank's (2010) WDI database, measured in kilograms of oil equivalent per capita. Like per capita GDP and $C0_2$ emissions, these data are logged in the model. Real figures are reported in Table 1, however, finding a mean value of 4462.718 and a range from 1705.687 to 8162.706. These values analyzed together demonstrate a distribution fairly close to normal.

The tenth hypothesis takes from Poloni-Staudinger's (2008) research to posit that as the rate of urbanization increases, public renewable R&D intensity will also increase. These data points come from The World Bank's (2010) WDI database as a percentage of the total population living in urban areas. These values appear to be distributed normally from 48.54 to 97.04 with a mean value of 73.82774, as reported in Table 1.

The final hypothesis contends that as levels of nuclear energy R&D increase, public renewable R&D intensity will decrease. These data points come from the IEA (2009) measured in millions of constant 2008 USD. I multiply these values by one million, converting them to constant 2008 USD. Nuclear energy R&D in constant 2008 USD data are logged in the model for a more normal distribution curve. Table 1 reports a range from 41000 to $2.98*e^9$ and a mean value of $3.04*e^8$ USD.

Research Scope and Methodology

This research uses cross-sectional time-series analysis. Panels of nineteen OECD countries across eleven years (1990-2000) compose the scope of the study. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. This research is restricted to OECD countries for two reasons. The first is that availability of data measuring renewable energy R&D provided by the IEA only covers OECD countries. Second, I find credibility in the argument that less developed countries are not likely to be very invested in renewable energy research and development. Less developed countries tend to have more pressing concerns such as ensuring clean drinking water, developing infrastructure such as a system of roads or medical facilities, and growing an economy. Unfortunately excluded are China and India, two countries with large and growing energy needs, economies, and technology sectors. Additionally regrettable, data limitations prevent large energy suppliers of world energy such as Saudi Arabia, Venezuela, Kuwait, the United Arab

Emirates, Libya, Russia, Mexico, Brazil, and other OPEC countries from being included in quantitative analysis.

The methodology of this research follows that advocated by Beck and Katz (1995) when using cross-sectional time-series analysis. Cross-sectional time-series data examines repeated observations on a fixed unit of analysis (a country in this case). Beck and Katz (1995) contend such analysis makes the use of ordinary least squares (OLS) regression problematic. These problems surface in the form of a downward bias in standard errors and an upward bias in t-statistics. Beck and Katz (1995) assert cross-sectional time-series data often allows for "temporally and spatially corrected errors, as well as for heteroscedasticity" (634). On their recommendation, this study employs the use of panel-corrected standard errors while keeping other OLS parameter estimates[7]. Reading cross-sectional time-series regression results that include panel-corrected standard errors, therefore, is effectively no different than OLS multivariate regression results.

Checking for multicolinearity between independent variables is important before running the model. Table 2 offers correlation statistics for all determinant variables. All of the variables correlate at a level below the general standard of .7 considered problematic. That said, it is worth noting the highest correlation is .6956, found between logged carbon dioxide emissions and logged energy use. A strong correlation was predicted in the previous section as pollution is a by-produce of energy use; justification for the inclusion of both variables in the model is also given these. Another correlation worth noting is government type (single party majority to surplus coalition) and the effective number of legislative parties, at .6269. This level of correlation is not all that

[7] This method is achieved in STATA by using the command line, "xtpcse dv iv_1 iv_2 iv_3 . . ."

surprising if we consider an increased number of parties as a precondition in the need for coalition building. A correlation value of .6078 between government type and green party strength makes intuitive sense; a coalition government is likely to coincide with increased legislative seats held by minor parties such as the greens. Per capita GDP is a measure of economic well-being, which is linked to capitalist production. Production necessitates energy use, thus explaining the correlation of .5807 between per capita GDP and energy use. All other correlation values are low enough that problems of multicolinearity are not a concern.

Table 2: Correlation Statistics

	Regime Type	Democracy Type	Legislative Electoral System Type	Government Type	Number of Effective Legislative Parties	Green Party Strength	Per Capita GDP (logged)	Carbon Dioxide Emissions (logged)	Energy Use (logged)	Urbanization %	R&D Nuclear Energy (logged)
Regime Type	1.000										
Democracy Type	-.2148	1.000									
Legislative Electoral System Type	.0308	.4155	1.000								
Government Type	.1275	.2877	.3670	1.000							
Number of Legislative Parties	.0464	.2617	.4676	.6269	1.000						
Green Party Strength	.0800	.2256	.4242	.6078	.5235	1.000					
Per Capita GDP (logged)	.2171	-.1436	-.2578	.2892	.2564	.1344	1.000				
Carbon Dioxide Emissions (logged)	.0285	-.3517	-.5073	-.1566	-.1667	-.1422	.2939	1.000			
Energy Use (logged)	.1659	-.2772	-.3840	-.0083	.0601	.0620	.5807	.6956	1.000		
Urbanization %	-.1728	-.1107	-.3274	-.1256	.1806	-.0627	.3676	.3221	.4465	1.000	
R&D Nuclear Energy (logged)	.1990	-.2551	-.5309	.1255	-.0193	-.0777	.4646	.2898	.3646	.1962	1.000

Results and Analysis

Table 3 reports linear regression results of my dependent variable on eleven independent variables using panel-corrected standard error methods advocated by Beck and Katz (1995). Two of the six political variables, regime type and legislative electoral system, as well as all five control variables prove to be statistically significant. The full model is also statistically significant with a .000 probability value. An R^2 value of .5945 indicates the model captures almost 60% of the variation in public renewable energy R&D intensity. Furthermore, the large Wald chi^2 score of 39,943.32 is indicative of strength in the model's findings. The way I interpret the results is by first analyzing the six political variables, then analyzing the five controls.

Table 3: Linear Regression Results Predicting Renewable Energy R&D Investment (Panel-Corrected Standard Errors)

Variable	Hypothesis #	Coefficient	Panel-Corrected Standard Error	T	P > |T|	95% Confidence Interval	
Regime Type	H_1	$9.26*e^{-6}$	$(3.18*e^{-6})$**	2.91	.004	$3.02*e^{-6}$	.0000155
Democracy Type	H_2	$2.86*e^{-6}$	$(8.22*e^{-6})$	0.35	.728	-.0000132	.000019
Legislative Electoral System Type	H_3	.0000314	$(1.86*e^{-6})$***	16.87	.000	.0000277	.000035
Government Type	H_4	$3.43*e^{-6}$	$(3.48*e^{-6})$	0.98	.325	$-3.40*e^{-6}$	.0000103
Number of Effective Legislative Parties	H_5	$-1.49*e^{-6}$	$(1.63*e^{-6})$	-0.91	.361	$-4.70*e^{-6}$	$1.71*e^{-6}$
Green Party Strength	H_6	$-5.06*e^{-7}$	$(8.44*e^{-7})$	-0.60	.548	$-2.16*e^{-6}$	$1.15*e^{-6}$
Per Capita GDP (logged)	H_7	.0000817	(.0000103)***	7.96	.000	.0000616	.0001018
Carbon Dioxide Emissions (logged)	H_8	.0000296	(.0000122)*	2.44	.015	$5.83*e^{-6}$	.0000535
Energy Use (logged)	H_9	-.0000437	$(2.73*e^{-6})$***	-15.96	.000	-.0000490	-.0000383
Urbanization %	H_{10}	$1.24*e^{-6}$	$(2.77*e^{-7})$***	4.48	.000	$7.00*e^{-7}$	$1.79*e^{-6}$
R&D Nuclear Energy (logged)	H_{11}	$-4.11*e^{-6}$	$(1.15*e^{-6})$***	-3.58	.000	$-6.35*e^{-6}$	$-1.86*e^{-6}$
Constant	---	-.0005528	(.0000882)***	-6.26	.000	-.0007257	-.0003798

Notes: N = 186; ***Significant at .001, **Significant at .01, *Significant at .05
R^2 = .5945; Wald chi^2 = 39943.32; Probability > chi^2 = 0.000

$$y = -.0005528 + 9.26*e^{-6}x_1 + 2.86*e^{-6}x_2 + .0000314x_3 + 3.43*e^{-6}x_4 – 1.49*e^{-6}x_5 – 5.06*e^{-7}x_6$$

$$+ .0000817x_7 + .0000296x_8 – .0000437x_9 +1.24*e^{-6}x_{10} – 4.11*e^{-6}x_{11}.$$

Political Variable Analysis

Panel-corrected standard error results of the linear regression model are reported in Table 3, indicating regime type (H_1) is statistically significant in the hypothesized direction. Presidential systems have higher levels of public renewable energy R&D intensity than parliamentary or mixed systems at a .01 confidence level. The coefficient for regime type is $9.26*e^{-6}$, meaning a one unit change in regime type leads to a $9.26*e^{-6}$ unit change in the dependent variable, holding all other variables constant. While this is a very small number and thus seems like an inconsequential change, remember that the dependent variable measures renewable energy R&D as a percentage of GDP. So a shift in regime type from parliamentary to mixed democracy or mixed to presidential democracy accounts for a $9.26*e^{-6}$ percent increase in renewable energy R&D dollars, holding all other variables constant. Multiplying the variable coefficient by the median value of GDP ($\$3.75*e^{11}$) yields the change in renewable energy R&D funding to be $3,472,500, holding all other variables constant. Multiplying by the mean value of GDP ($\$1.46*e^{12}$) to calculate the average change yields an even larger result of $13,519,600. What initially seemed like a small increase turned out to be a hefty chuck of change—an average increase in renewable energy R&D of over 13 million dollars per year. If the assumption classifying renewable energy R&D as a public good is granted, these statistically significant results strengthen Bueno de Mesquita et al.'s (2003) selectorate theory on increased provision of public goods in presidential democracies versus parliamentary and mixed forms. If the assumption is not granted, the theoretical addition to comparative politics is lost; but this research still adds the knowledge that presidential systems have higher levels of public renewable energy R&D intensity than parliamentary or mixed systems.

The classification of democracies by Lijphart (1984, 1999) as majoritarian or consensual led to multiple hypotheses in this study[8]. Legislative electoral system type (H_3) is the only of Lijphart's characteristics that proves to have a statistically significant impact on renewable energy R&D intensity. These results indicate proportional legislative electoral systems have higher levels of public renewable energy R&D intensity than mixed or majoritarian systems at a .01 confidence level. The coefficient is .0000314, meaning a one unit change in legislative system type is reflected by a .0000314 unit change in the dependent variable, holding all other variables constant. Using the mean value for GDP calculates a $45,844,000 average difference, between types of legislative electoral systems, holding all other variables constant. Using the median GDP value reduces this difference in R&D between types electoral system to $11,775,000, holding all other variables constant. Still, almost twelve million dollars toward renewable energy R&D on the median per year funds a lot of research.

A second characteristic of Lijphart's classification of democracies is the type of government composing the cabinet. A coefficient value of $3.43 * e^{-6}$ indicates the type of government (H_4) impacts renewable energy in the direction proposed, but a probability statistic of .325 means we cannot reject the null hypothesis with statistical confidence. Similarly, Lijphart's assertion that consensual democracies (H_2) experience higher governmental environmentalism than majoritarian democracies failed to be statistically significant ($p = .728$) by the dichotomous measure in this study. Lack of statistical significance suggests increases in renewable energy R&D are caused by other factors

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[8] (H_2), (H_3), (H_4), and (H_5) all expect positive correlations to renewable energy R&D.

than the government type holding cabinet office. While these results suggest correlation in the direction Lijphart theorizes, causation cannot be determined.

The type of party system (H_5) is the final characteristic in Lijphart's classifications used in this research. An extension from the effective number of legislative parties is the percentage of seats held by the green party (H_6). Both of these hypotheses expected a positive relationship, but Table 3 reports *negative* coefficients for both hypotheses, $-1.49*e^{-6}$ and $-5.06*e^{-6}$, respectively. These values mean that as the number of effective legislative parties and the percentage of legislative seats held by the green party increase, renewable energy R&D intensity *decreases*. Neither of these results are statistically significant, $p = .361$ and $.548$, but the directional correlation is itself interesting. One possible explanation could be that green party presence in the legislature demands substantive environmental policies, such as business regulations or protected areas of nature, thereby using up the party's political capital. Further research analyzing the strength of green parties and environmental improvements is needed to better understand these relationships.

This research found results consistent with Lijphart's theory that consensual democracies exhibit higher levels of governmental environmentalism than majoritarian democracies. However, only one of the three individual characteristics of consensual democracies Lijphart suggests proved to be statistically significant. In conjunction with the statistically insignificant dichotomous measure of consensual versus majoritarian democracy, this research is unable to offer overall empirical support to the theory.

Control Variable Analysis

Each of the five control variables proved to have a statistically significant impact on renewable energy R&D intensity. Of these five, however, only three were statistically significant in the expected direction. Increases in logged values of per capita GDP (H_7) and urbanization percentage (H_{10}) are met with increases in renewable energy R&D intensity. Respective coefficients of .0000817 and $1.24*e^{-6}$ indicate the change in renewable energy R&D intensity from a one unit increase in logged per capita GDP or urbanization percentage, holding all other variables constant. As hypothesized, nuclear energy R&D (H_{11}) is inversely correlated at a rate of $-4.11*e^{-6}$ renewable energy R&D dollars per nuclear energy R&D dollar, holding all other variables constant. All three variables boast probability scores of .000, meaning we can safely reject the null hypothesis.

Two control variables manage a statistically significant effect on renewable energy R&D intensity in the *opposite* direction than hypothesized. These are perhaps the most intriguing results of the study. Logged values of carbon dioxide emission (H_8) were expected to have an inverse effect on renewable R&D, while logged values of energy use (H_9) were expected to have a positive effect. Table 3 reports coefficient values for logged carbon dioxide (.0000296) and logged energy use (-.0000437) in the opposite directions. These values mean a logged metric ton per capita increase in carbon dioxide emissions statistically correlates to a .0000296 percentage increase in renewable energy R&D intensity, holding all other variables constant. We find a $43,216,000 increase in average annual renewable energy R&D funding for every logged metric ton per capita increase in carbon dioxide emission, holding all other variables constant. In the opposite direction, a coefficient for logged energy use indicates a one kilogram of oil equivalent per capita increase correlates with a -.0000437 percent change in renewable energy R&D intensity, holding all other variables constant. So, a one-unit increase of logged per capita kilograms of oil equivalent statistically correlates to an average $63,802,000 *decrease* in renewable energy R&D, holding all other variables constant.

Table 3 also reports probability figures for these two variables at .015 and .000, respectively, meaning we can reject the null hypotheses. These results are especially confounding when recalling their correlation figure is .6956, the highest value between any two independent variables. The reasons for these impacts on renewable energy R&D are elusive. One potential explanation could be higher carbon dioxide emissions are correlated with high levels of other pollutants which causes increasing demands from citizens for environmental improvements. Along a similar line of logic, countries with high governmental environmentalism may have policies in place to reduce energy use while simultaneously researching renewable energy. Since the effects on renewable energy R&D were opposite than expected, both these variables are needed in further study.

The main political hypotheses survived the imposition of the control variables well. All told, five of the eleven hypotheses proved to be statistically significant in the expected direction (H_1, H_3, H_7, H_{10} and H_{11}); two were made in the correct direction, but lacked statistical significance (H_2 and H_4); two were neither in the expected direction or statistically significant (H_5 and H_6); and two of the hypotheses proved to have a statistically significant impact on renewable energy R&D in the direction *opposite* than expected (H_8 and H_9).

Summary and Contribution to Research

Of the six political variables, regime type and legislative electoral system type proved to be the only two with statistically significant results. The findings suggest that presidential democracies with proportional legislative electoral systems have higher levels of renewable energy R&D than parliamentary democracies with majoritarian electoral systems. All five control variables were statistically significant, but carbon dioxide emissions (directly) and energy use (inversely) influence renewable energy R&D in the opposite direction than expected.

The addition of this research to the cumulative knowledge of comparative politics is mixed. I suggest additional empirical support is found for Bueno de Mesquita et al.'s (2003) selectorate theory through this research. I will concede that the classification of renewable energy R&D funding as a public good is open to challenge. This study does find support for a characteristic of democracies studied by Lijphart (1984, 1999) and others - legislative electoral systems. Unfortunately, no statistical evidence arises in this study for other political institutions that Lijphart claims work in the same manner, such as government type and effective number of parties. The effect of per capita GDP on renewable energy R&D is statistically significant, but cannot fully speak to Grossman and Krueger's (1995) EKC research. This is the case because my research uses data from only one side of the inverted-U curve, therefore preventing sweeping generalizations to the curve.

The findings of this study also have important application for policymakers. As Komen et al. (1997) propose, results "may be indicative of future developments in [developing] countries when they reach income levels that are within the range spanned by the OECD" (507). As just mentioned, however, a cautious extension of these results should be made to developing countries. Komen et al. (1997) focused on per capita GDP, however regime shifts from dictatorship to democracy could be realized. Alternatively, a future research project could determine if linkages exist between renewable energy investment and production, thereby determining if any particular renewable energy technology options are significantly more efficient at converting funding into useable energy.

This study can be improved in a few ways. There is always demand for more thorough and complete data. Restrictions in the data prevented inclusion of some important countries such as China and India. Both have expanding influence in the global economy and represent a large share of global energy demand. Additionally, major players in the global supply of energy such as Saudi Arabia, Venezuela, Kuwait, the United Arab Emirates, Libya, Russia, Mexico, Brazil, or other OPEC countries could provide excellent cases for research.

An additional limitation is the uncertainty associated with how funding appropriated for renewable energy R&D is distributed throughout a country. Komen et al. (1997) raise an excellent possibility that funding may be in the form of industrial subsidies. Examining the role and different types of subsidies could be a direction future research takes on this topic. The effect of state ownership of energy enterprises on subsidies would be an interesting relationship to examine. Other directions for future comparative research may be the impact of fossil fuel reserves on research and development. Perhaps countries with large stores of reserves do not feel the true economic cost for fossil fuel-based energy. A much broader set of literature might address the private sector's role in the future of energy. This strand of research could tie foreign direct investment (FDI) to private development of renewable energy or small-scale green projects.

Further study with an economic focus may wish to alter the dependent measure of renewable energy R&D. One alteration may be to measure the change in R&D intensity from year to year. Economic determinants may be able to explain an increase of three percent from 1992-1993 with a decrease of ten percent from 1994-1995 in Country X. Comparative political scientists may wish to alter the dependent measure as well. Measuring renewable energy R&D as a percentage of total energy R&D would allow insight into the budgetary allocation process. A quick look at the determinant variables from this research on renewable energy R&D over total energy R&D concludes all statistically significant variables influence the dependent variable in the direction of my original study. With this new dependent measure the effective number of legislative parties and strength of the green party are the most intriguing results. Against this new measure both are statistically significant, but green party strength has a direct relationship while that to the number of parties is inverse. Within literature on the bureaucratic process, one avenue might be to analyze the role of committee systems with gatekeeping powers to set the agenda and add amendments.

A short normative note is due here. Research and development for our future energy needs is extremely important. The future of energy is one of the most important unanswered questions for the direction humanity goes into the twenty-first century. Research and development in the wealthiest OECD countries may make a breakthrough in our technology to provide global energy. Such a breakthrough may allow developing countries to avoid high pollution levels while industrializing; most agree that would be a huge benefit to the global community. Finally, I suggest that institutions that perceive a tradeoff between economic growth and environmental protection are misguided. Sustainable environmental policies not only make economic sense, but they create wealth in the continued existence of humanity. That is why further research and development on sustainability is required, and why understanding who does this research and why is important.

References

Armingeon, K., Potolidis, P., Gerber, M., and Leimgruber, P. (2009). "Comparative Political Data Set I, 1960-2007". Institute of Political Science, University of Berne, Switzerland.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C. and Pimentel, D. (1995). "Economic growth, carrying capacity, and the environment". *Ecological Economics* 2: 91-95.

Barrett, S. and Graddy, K. (2000). "Freedom, growth, and the environment". *Environment and Development Economics* 5 (4): 433-456.

Battig M. B. and Bernauer, T. (2009). "National institutions and global public goods: are democracies more cooperative in climate change policy?". *International Organization* 63 (2): 281-308.

Beck, N. and Katz, J. N. (1995). "What to do (and not to do) with time-series cross-section data". *American Political Science Review* 89 (3): 634-647.

Bernauer, T. and Koubi, V. (2009). "Effects of political institutions on air quality". *Ecological Economics*. 68: 1355-1365.

Breukers, S. and Wolsink, M. (2007). "Wind Energy Policies in the Netherlands: Institutional Capacity-Building for Ecological Modernisation" *Environmental Politics* 16 (1): 92-112.

Bueno de Mesquita, B., Smith, A., Siverson, R. and Morrow, J. (2003). *The Logic of Political Survival*. Cambridge, MA: The MIT Press.

Congleton, R. (1992). “Political institutions and political control”. *The Review of Economics and Statistics* 74 (3): 412-421.

Crepaz, M. M. L. (1995). “Explaining national variation in air pollution levels: Political institutions and their impact on environmental policymaking”. *Environmental Politics* 4 (3): 391-414.

Crepaz, M. M. L. (1996). “Consensus versus majoritarian democracy: Political institutions and their impact on macroeconomic performance and industrial disputes”. *Comparative Political Studies* 29 (1): 4-26.

Darwin, C. G. (1952). *The Next Million Years*. New York, NY: Doubleday & Company.

Deacon, R. (2003). "Dictatorship, democracy, and the provision of public goods". University of California at Santa Barbara, *Economics Working Paper Series* 20-03, Department of Economics, UC Santa Barbara.

Doornbosch, R. and Upton, S. (2006). “Do we have the right R&D priorities and programmes to support the energy technologies of the future?”. OECD. Round Table on Sustainable Development, June 14-15. Paris, France.

Fouquet D. and Johansson, T. B. (2008). “European renewable energy policy at crossroads—Focus on electricity support mechanisms”. *Energy Policy* 36 (11): 4079-4092.

Golder, M. (2005). “Democratic electoral systems around the world, 1946-2000”. *Electoral Studies* 24: 103-121.

Grossman, G. and Krueger, A. (1995). Economic growth and the environment. *Quarterly Journal of Economics* 110 (2): 353-377.

Guellec, D. and Van Pottelsberghe de la Potterie, B. (2001). "R&D and productivity growth: panel data analysis of 16 OECD countries". OECD STI working papers 2001/3. Paris, France.

Hepbasli, A. (2008). "A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future". *Renewable and Sustainable Energy Reviews* 12 (3): 593-661.

Hettige, H., Lucas, R. E. B. and Wheeler, D. (1992). "The toxic intensity of industrial production: global patterns, trends, and trade policy". *American Economic Review* 82: 478-481.

Holtz-Eakin, D. and Selden, T. M. (1995). "Stoking the fires? CO_2 emissions and economic growth". *Journal of Public Economics* 57: 85-101.

Inglehart, R. (1995). "Public support for environmental protection: objective problems and subjective values in 43 Societies". *Politics and Society* 28 (1): 57-71.

International Energy Agency (IEA) (2009). "Energy technology R&D budgets: beyond 2020 documentation". http://iea.org/stats/rd.asp. [Login as guest for free access].

Joselin Herbert, G. M., Iniyan, S., Sreevalsan, E. and Rajapandian, S. (2007). "A review of wind energy technologies". *Renewable and Sustainable Energy Reviews* 11 (6): 1117-1145.

Komen, M. H. C., Gerking, S. and Folmer, H. (1997). "Income and environmental R&D: empirical evidence from OECD countries". *Environment and Development Economics* 2: 505-515.

Kuznets, S. (1955). "Economic Growth and Income Inequality". *American Economic Review* 45: 1-28.

Lake, D. and Baum, M. (2001). "The invisible hand of democracy: political control and the provision of public service". *Comparative Political Studies* 34 (6): 587-621.

Langniß, O., Diekmann, J. and, Lehr, U. (2008). "Advanced mechanisms for the promotion of renewable energy—Models for the future evolution of the German Renewable Energy Act". *Energy Policy* 37 (4): 1289-1297.

Li, Q. and Reuveny, R. (2006). "Democracy and environmental degradation". *International Studies Quarterly* 50 (4): 935-956.

Lijphart, A. (1984). *Democracies: Patterns of majoritarian and consensus government in twenty-one countries*. New Haven, CT: Yale University Press.

Lijphart, A. (1999). *Patterns of democracy: Government forms and performance in thirty-six countries*. New Haven, CT: Yale University Press.

Lijphart, A. and Crepaz, M. M. L. (1991). "Corporatism and consensus democracy in eighteen countries: conceptual and empirical linkages". *British Journal of Political Science* 21: 235-256.

Marchetti, J. M., Miguel, V. U. and Errazu, A. F. (2007). "Possible methods for biodiesel production". *Renewable and Sustainable Energy Reviews* 11 (6): 1300-1311**.**

Margolis, R. M. and Kammen, D. M. (1999). "Evidence of under-investment in energy R&D in the United States and the impact of federal policy". *Energy Policy* 27 (10): 575-584.

McGuire, M. and Olson, M. (1996). "The economics of autocracy and majority rule: the invisible hand and the use of force". *Journal of Economic Literature* 34: 72-96.

Midlarsky, M. (1998). "Democracy and the environment: an empirical assessment". *Journal of Peace Research* 35 (3): 341-361.

Mol, A. P. J. (2001). *Globalization and Environmental Reform*. Cambridge, MA: The MIT Press.

Mol, A. P. J. and Spaargaren, G. (2000). "Ecological modernisation theory in debate: a review". *Environmental Politics* 9 (1): 17-49.

Neumayer, E. (2003). "Are left-wing party strength and corporatism good for the environment? Evidence from panel analysis of air pollution in OECD countries". *Ecological Economics* 45 (2): 203-220.

Olson, M. (1993). "Dictatorship, democracy and development". *American Political Science Review* 87 (3): 567-576.

Poloni-Staudinger, L. M. (2008). "Are consensus democracies more environmentally effective?". *Environmental Politics* 17 (3): 410-430.

Persson, T., Roland, G. and Tabellini, G. (2000). "Comparative politics and public finance". *Journal of Political Economy*: 108 (6): 1121-1141.

Scruggs, L. (1999). "Institutions and environmental performance in seventeen western democracies". *British Journal of Political Science* 29 (1): 1-31.

Scruggs, L. (2001). "Is there really a link between neo-corporatism and environmental performance? Updated evidence and new data for the 1980s and 1990s". *British Journal of Political Science* 31 (4): 686-692.

Scruggs, L. (2009). "Democracy and environmental protection: an empirical analysis". Presented at the Midwest Political Science Association conference, April 2-5.

Segers, R. (2008). "Three options to calculate the percentage renewable energy: An example for a EU policy debate". *Energy Policy* 36 (9): 3243-3248.

Selden, T. M. and Song, D. (1994). “Environmental quality and development: Is there a Kuznets curve for air pollution emissions?”. *Journal of Environmental Economics and Management* 27: 147-162.

Shafik, N. (1994). “Economic development and environmental quality: an econometric analysis”. *Oxford Economic Papers* 46: 757-773.

Stern, D. I. (2004). “The rise and fall of the environmental Kuznets curve”. *World Development* 32 (8): 1419-1439.

Stern, D. I., Common, M. S. and Barbier, E. B. (1996). “Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development”. *World Development* 24: 1151-1160.

The World Bank (2010). World Development Indicators database (WDI). http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=2.

Thirugnanasambandam, M., Iniyan, S. and Goic, R. (2010). “A review of solar thermal technologies”. *Renewable and Sustainable Energy Reviews* 14 (1): 312-322.

Toke, D. (2005). “Explaining wind power planning outcomes: some findings from a study in England and Wales”. *Energy Policy* 33 (12): 1527-1539.

York, R., Rosa, E. and Dietz, T. (2003). “Footprints on the earth: the environmental consequences of the modernity”. *American Sociological Review* 68: 279-300.

Yüksel, I. (2010). “Energy production and sustainable energy policies in Turkey”. *Renewable Energy* 35 (7): 1469-1476.