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FACTORS OF RENEWABLE ENERGY DEPLOYMENT AND EMPIRICAL STUDIES OF UNITED STATES WIND ENERGY

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Policy Studies

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by
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December 2017

Accepted by:
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ABSTRACT

Considered essential for countries' development, energy demand is growing worldwide. Unlike conventional sources, the use of renewable energy sources has multiple benefits, including increased energy security, sustainable economic growth, and pollution reduction, in particular greenhouse gas emissions. Nevertheless, there is a considerable difference in the share of renewable energy sources in national energy portfolios. This dissertation contains a series of studies to provide an outlook on the existing renewable energy deployment literature and empirically identify the factors of wind energy generation capacity and wind energy policy diffusion in the U.S.

The dissertation begins with a systematic literature review to identify drivers and barriers which could help in understanding the diverging paths of renewable energy deployment for countries. In the analysis, economic, environmental, and social factors are found to be drivers, whereas political, regulatory, technical potential and technological factors are not classified as either a driver or a barrier (i.e., undetermined). Each main category contains several subcategories, among which only national income is found to have a positive impact, whereas all other subcategories are considered undetermined. No significant barriers to the deployment of renewable energy sources are found over the analyzed period.

Wind energy deployment within the states related to environmental and economic factors was seldom discussed in the literature. The second study of the dissertation is thus focused on the wind energy deployment in the United States. Wind energy is among the most promising clean energy sources and the United States has led the world in per capita newly installed generation capacity since 2000. In the second study, using a fixed-effects panel data regression analysis, the significance of a number of economic and environmental factors are investigated for 39 states from 2000 to 2015. The results suggested that the increase in economic factors is related to a significant increase in the installed wind energy capacity, whereas, the increase in environmental factors is related to a significant decrease in the installed wind capacity.

The final study explores the factors of diffusion of state- and local-level wind energy support policies which are considered fundamental factors of the continuum and development of wind power in the United States. To reveal the internal determinants of state's wind energy policy diffusion, we further narrow the scope and control for the geographical region in the final study. We limit our analysis to seven neighboring Midwestern states, which are located in the center of United States wind energy corridor. Using data from 2008 to 2015, the study investigates the significance of the following internal factors: wind power potential, per capita gross state product, unemployment rate, per capita value of the agriculture sector, number of establishments in agricultural sector, and state government control. Through the addition of interaction terms, the study also considers the behavioral differences in the explanatory variables under Republican and non-Republican state governance. Our findings suggest that the economic development potential and related environmental benefits were the common motivation for state- and local-level policy makers. Lastly, technical terms and agricultural sector presence provides additional motives for the state level diffusion of wind energy policies.

The findings of this dissertation are expected to contribute to the understanding of how countries and states might best stimulate and support renewable energy, and in particular wind energy, deployment.

DEDICATION

To my precious daughter Lidya,

I would not have gotten through this doctorate if it were not for her.

&

To my beloved Ali,

Who started this journey with me, was always there for me, but sadly did not make it to the end. I will always love and remember him.

ACKNOWLEDGMENTS

Many thanks are due to my advisors and committee members for their guidance and patience. Dr. Julia L. Sharp and Dr. Annick Anctil, I am incredibly appreciative of the amount of time, effort, and expertise that you contributed to my dissertation work. Dr. Lori Dickes, I will always be appreciative of your support throughout my degree and my research. Finally, Dr. Bruce Ransom, thank you for your time and patience throughout my Ph.D. studies as our program director, and especially as my committee member.

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Finally, an enormous debt of gratitude is owed to my husband for providing me with unfailing support and continuous encouragement throughout my years of doctoral study and through the process of researching and writing this dissertation. This accomplishment would not have been possible without you. Love you.

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CHAPTER ONE

INTRODUCTION

Since the Industrial Revolution, energy has been recognized as a cross-cutting contributor to the achievement of countries' economic and social development goals [1], and as a result, the demand for energy has been growing worldwide [2]. Since then, fossil fuels remain the primary source of energy despite their multiple disadvantages, including being nonrenewable, being dependent on highly volatile energy prices and on supplier nations, and the release of air emissions. Among these disadvantages, air emissions are most recognized because fossil fuels are considered the largest contributors to the increase in greenhouse gas emissions.

Anthropogenic increase in greenhouse gas concentrations is considered to be the primary source of heat retention in the Earth's atmosphere, and therefore, contributes to increasing changes in climate [3]. Even though there has been a growing interest in renewable energy sources, especially since 2005 when the Kyoto Protocol was put into effect and set binding targets for countries [4], the use of renewable energy sources has remained low compared to the use of fossil fuels worldwide [2]. According to the latest data available by the World Bank, renewable energy production represents 17% to 18.5% of the total global energy production per person for the last 20 years [2]. In addition, there is still a considerable difference in the share of renewable energy sources in energy portfolios of countries. According to the Renewable Energy Policy Network for the 21st

Century (REN21), the share of non-hydro renewables in the global electricity portfolio was only 7.9% (921 gigawatts) in 2016 [5]. In addition, 54.3% of the renewable electricity was produced in three leading countries, namely China (28%), the U.S. (15.7%) and Germany (10.6%) [5]. While Japan, India and Italy produced 14.1% of the electricity from non-renewable sources of energy, 31.6% of the renewable electricity globally produced by the remaining countries [5]. At this point, there is not a clear understanding why certain countries may favor renewable energy over fossil fuels.

The first objective of this dissertation is to investigate which factors are associated with renewable energy deployment for various countries. The literature available on the drivers and barriers explaining the diversity of countries' renewable energy deployments presents inconsistent findings, which may be due to varying study research design (e.g. quantitative or qualitative), sampling variation, or other factors (e.g. data availability). This dearth of literature may also be due to a wide range of political, social, cultural, or economic factors. Chapter Two systematically identifies and categorizes factors of national renewable energy deployment using a formal systematic literature review process and a one-sample proportion statistical analysis. We do not limit our analysis to any particular country or type of renewable energy source in this study. The overarching goal is to aid in the understanding of countries' renewable energy deployment decisions. The designated manuscripts from the literature review are explored in detail with a focus on the renewable energy sources referenced, the publication years, the countries presented, and the length of the studies to identify additional trends. The systematic review will allow future researchers to identify additional research gaps and priorities in investigating renewable energy source deployment, and to avoid unnecessary duplication of research. Researchers will also be able to update this review and integrate new findings considering reproducible structure of the methodology.

Since 2000, wind energy has substantially increased its share in the global energy portfolio and the U.S. has led the world in per capita newly installed generation capacity [6]. In 2016, wind energy had the highest share among non-hydro renewable sources of electricity [5]. Since 2000, the literature focused on factors of renewable energy deployment in the United States was limited in scope. Specifically, wind energy deployment within the states related to environmental and economic factors was seldom discussed in the literature. Chapters Three and Four address several important gaps in the existing renewable energy deployment literature (i.e. study of variables that have not been considered in the current literature and an explicit definition for the renewable energy type studied) and focuses on the U.S. wind energy.

In Chapter Three we investigate the significance of a number of economic and environmental factors of U.S. wind energy from 2000 to 2015 using a fixed-effects panel data regression analysis. Economic factors include gross state product, the value of the agricultural sector, and the unemployment rate, and environmental factors include carbon dioxide emissions, nitrogen oxide emissions, and water use. The findings are expected to contribute to the understanding of how developed nations, like the U.S., might best stimulate and support wind energy deployment.

While Chapter Three focused on economic and environmental factors that cannot be directly changed, the literature agrees that the policy environment and enabling structure of this policy environment are crucial for the successful and effective promotion, and resulting use of renewable energy sources [7], [8]. In Chapter Four, we use Berry and Berry's dynamic model for the analysis of internal and external factors of policy diffusion. To control for the external factors of policy diffusion (i.e. geographical interaction), we focus on seven Midwestern states and investigate the internal factors related to the diffusion of wind energy policies. Using the data from 2008 to 2015 and a random-effects panel model, in Chapter Four, we empirically explore the significance of the following internal factors: technical (wind power potential), economic (per capita gross state product, unemployment rate), agricultural sector specific (per capita value of the agriculture sector, number of the establishments in agricultural sector) and political (state government control). Through the addition of interaction terms in this empirical analysis, we also consider the behavioral differences in the determinants of the diffusion of wind energy policy under Republican and non-Republican state governance. The findings of this empirical study are expected to provide useful guidance to policy makers on the significance and size of the factors influencing wind energy policy diffusion in the U.S. Chapter Five summarizes the findings from Chapter Two to Four and provides additional research suggestions and key conclusions.

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[1] W. F. Sawin J., Seyboth K., “Renewables 2017 Global Status Report,” 2017.

CHAPTER TWO

FACTORS IMPACTING DIVERGING PATHS OF RENEWABLE ENERGY: A REVIEW

Abstract

Considered an essential factor for countries' development, energy demand is growing worldwide. Unlike conventional sources, the use of renewable energy sources has multiple benefits, including increased energy security, sustainable economic growth, and pollution reduction, in particular greenhouse gas emissions. Nevertheless, there is a considerable difference in the share of renewable energy sources in national energy portfolios. This study conducts a systematic literature review to identify drivers and barriers which could help understanding the diverging paths of renewable energy deployment for countries. Among a total of 1431 academic studies, 60 qualitative and quantitative studies were identified using a multistage selection process. Designated manuscripts were explored in detail including publication years, length of the studies, countries represented, and renewable energy sources referenced. Factors explaining countries' renewable energy deployments were defined and organized into seven main categories: economic, environmental, political, regulatory, social, technical potential, and technological. Within these categories, economic considerations appeared most frequently across manuscripts, while environmental factors were least represented. These categories were then classified as drivers, barriers or undetermined towards renewable energy deployment based on a one-sample proportion statistical test. Economic, environmental,

and social factors were found to be drivers, whereas political, regulatory, technical potential and technological factors were not classified as either a driver or a barrier (i.e., undetermined). Each main category contains several subcategories, among which only national income was found to have a positive impact, whereas all other subcategories were considered undetermined. No significant barriers to the deployment of renewable energy sources were found over the analyzed period.

1. Introduction

Energy is recognized as a crosscutting contributor to the achievement of countries' economic and social development goals [1]. As a result, there is worldwide growth in energy demand (Figure 1). The latest global financial crisis in 2008 highlighted the close link between energy security and continuous economic growth. Unlike fossil fuels, which are non-renewable and considered the largest contributor to the increase in anthropogenic greenhouse gas concentrations [2], renewable energy sources cannot be depleted, and their use releases little or no additional CO_2 back into the atmosphere [3]. Increasing the use of renewable resources contributes to the economic growth and greenhouse gas mitigation of countries.

The growing threat posed by climate change to the economic, social, and environmental welfare of countries was first recognized in 1979 by the World Climate Conference, which called on governments "to foresee and prevent potential man-made changes in climate" [4]. The Kyoto Protocol was the first international treaty that set binding targets to reduce greenhouse gas emissions for participating countries.[i] It was adopted in 1997, became effective in 2005, and was signed by 89 countries (including the United States) by 2009 [5]. Ratified by 191 states (excluding the United States) and one regional economic integration organization (European Union) between 1998 and 2013 [5],

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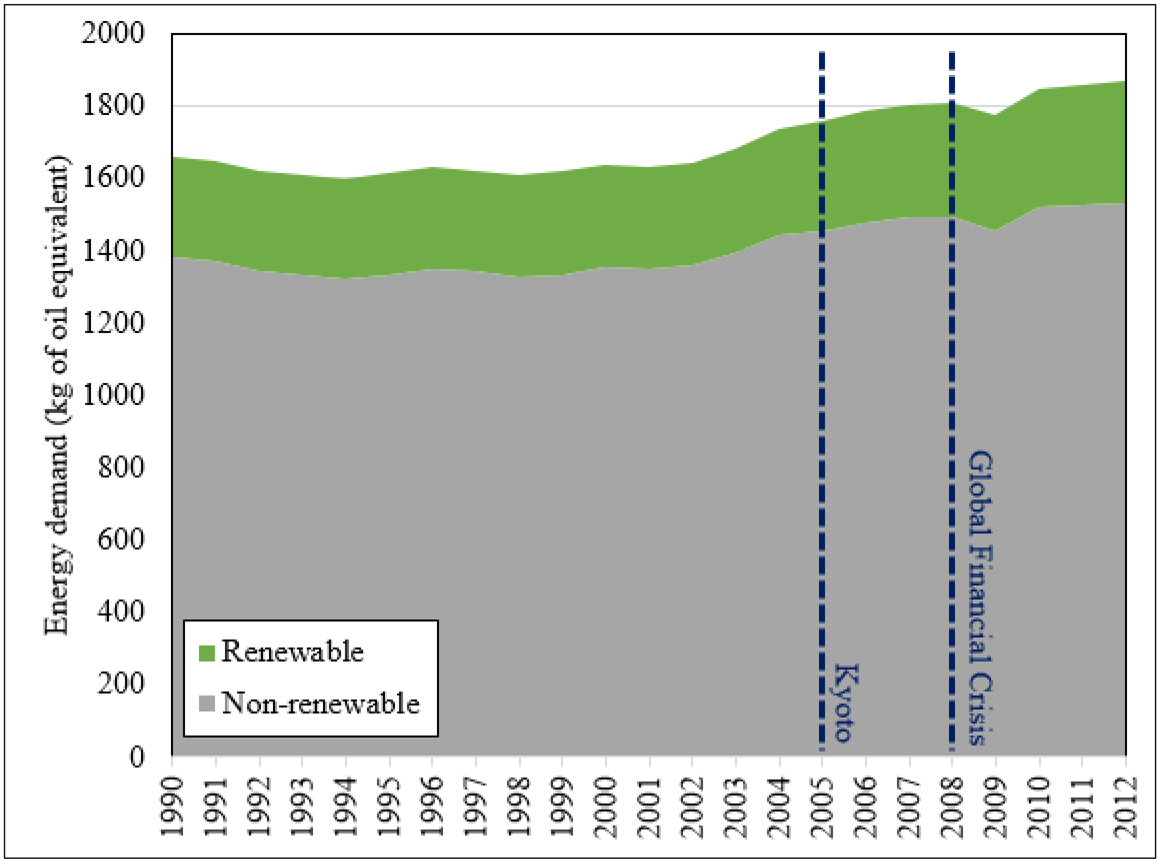
[i] The Protocol has two commitment periods. First commitment period started in 2008 and ended in 2012. During this period, 37 industrialized countries and the European Community committed to reduce GHG emissions by an average of 5% from their 1990 levels. The second period started in 2013 and ends in 2020. During the second commitment period, Parties committed to reduce greenhouse gas emissions by at least 18% below 1990 levels. The composition of Parties in the second commitment period is more comprehensive than the Parties of first commitment period.

the Kyoto Protocol is considered a “historic milestone” in the fight against the increase in greenhouse gas emissions [6]. Since 2005, when the Kyoto Protocol came into effect, there has been a growing interest in greenhouse gas mitigation strategies, including the increased use of renewable energy sources.

Figure 1. Global energy demands (data from [7])



Despite its benefits, renewable energy consumption accounts for less than 17% of the total energy demand per person worldwide and this proportion has only increased by 1.5% in 20 years (Figure 1). Of particular interest for this work is the difference in the share of renewable energy sources of individual countries. At this point, there is no clear understanding why certain countries may favor renewable energy over traditional energy sources.

The literature available on the drivers and barriers explaining the diversity of countries' renewable energy deployments presents inconsistent findings. The inconsistencies may be due to varying study research designs (e.g., quantitative or qualitative), sampling variation, or other factors (e.g., data availability). To compare results among studies, a systematic review of the literature is required. One study was published on the subject in 2014 but focused on only the drivers and four types of renewable energy sources (wind, solar, biomass, and wave energy) in eight European countries (United Kingdom, Sweden, Italy, France, Germany, Netherlands, Spain, and Ireland) [8].

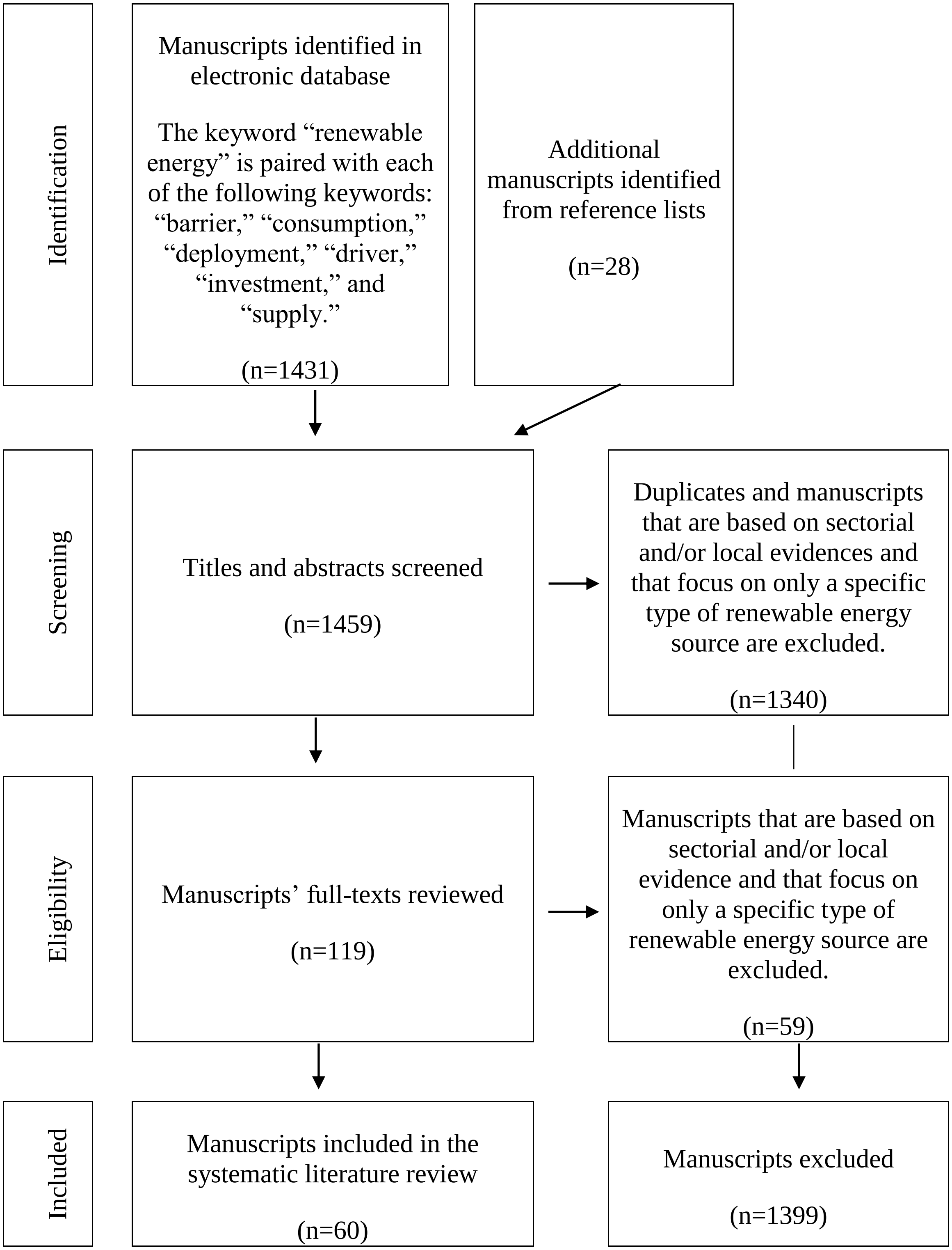
This research, by comparison, does not limit the scope to any specific renewable energy source or country. The objective is to identify and categorize factors as drivers and barriers of renewable energy source deployment using a formal systematic literature review process [9] and a one-sample proportion statistical analysis. The overarching goal is to aid in the understanding of countries' renewable energy deployment decisions. The designated manuscripts from the literature review were explored in detail with a focus on the renewable energy sources referenced, the publication years, the countries represented, and the length of the studies to identify additional trends. The current systematic study will allow future researchers to identify additional research gaps and priorities in investigating renewable energy source deployment, and to avoid unnecessary duplication of research. Researchers will also be able to update this review and integrate new findings considering the reproducible structure of the methodology.

2. Methodology

This literature review aims to systematically identify, select, and evaluate the current state of knowledge on the drivers and barriers (from here on, referenced as "factors") of countries' decision-making processes for renewable energy deployment. Using a multistage selection process, 60 quantitative and qualitative studies (from here on, referenced as "focal manuscripts") were identified out of 1431 screened academic manuscripts extracted from three comprehensive databases (Science Direct, JSTOR, and Google Scholar).

Systematic literature reviews are essential to answer clearly-formulated research questions by gathering together all available published academic work. Poor reporting of the literature diminishes the value of the answer to the research question for policy makers, future scholars, and other users. In this review, manuscripts were selected according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which ensures a transparent and complete reporting in the selection process of manuscripts for systematic literature reviews [9]. The PRISMA statement offers a practical process to review literature that is implemented in three phases: (i) identification, (ii) screening, and (iii) eligibility as summarized in Figure 2 [10].

Figure 2. Flow diagram of the selection process of manuscripts identified through the PRISMA statement [10]



The identification phase of the PRISMA statement process involves searching databases using all key search terms and applying appropriate limits of the search (e.g., years of search, language of search, etc.) [11]. The articles identified through sources other than databases (i.e., manual searches through reference lists) are also included in the review process in the identification phase [11]. In this study, the identification phase included a search of Science Direct, JSTOR, and Google Scholar databases for relevant manuscripts using the keyword “renewable energy” combined with each of the following keywords: “barrier,” “consumption,” “deployment,” “driver,” “investment,” and “supply” (e.g., “renewable energy” and barrier, “renewable energy” and consumption, etc.). The paired key search terms were entered individually into each database; the search was limited to studies published in the English language and after the year 2005. The focus on studies published after 2005 was due to CO_2 emissions reporting and reduction requirements in order to comply with the Kyoto Protocol. The year 2005 was a turning point since the emission targets became binding commitments and the market-based greenhouse gas emission trading mechanisms of the Protocol became fully operational at that time. A total of 1431 manuscripts related to the factors and decisions for renewable energy deployment were identified in the identification phase. In addition, we identified 28 relevant manuscripts from the initial reference lists of these 1431 manuscripts.

The screening phase necessitates scanning the title and abstract of the manuscripts for articles that are relevant to the research question. The objective is to separate the articles that appear to provide an answer to the research question from those that are irrelevant [11]. In this study, titles and abstracts of the initially identified 1459 manuscripts (1431 from the databases search and 28 from the reference lists search) were screened, focusing on factors that contribute to the renewable energy deployment decisions of countries. A total of 119 manuscripts remained at the end of screening phase. 1340 manuscripts were excluded based upon their focus on sectorial and/or local evidence and/or on only one renewable energy source. The objective of this study was to review the literature that focuses on the nationwide decision-making processes of renewable energy deployment. Manuscripts focusing on the factors of renewable energy deployment decisions limited to a particular industry (e.g., agriculture, transportation, etc.) or specific to a particular region (i.e., any city, region or state) of a country were excluded due to the lack of representation of these studies. Similarly, manuscripts limiting their analysis to a single type of renewable energy source (e.g., wind, solar, etc.) were not included for the systematic literature review. The scope of these studies were narrow and contradicted the broad scope of the systematic literature review.

The eligibility phase requires the inspection of full-text articles to be included in the final review [11]. In this final phase, 119 manuscripts were read fully, and 60 focal manuscripts were identified as relevant for the systematic literature review. Similar to the screening phase, manuscripts based upon sectorial and/or local evidence and that focus on only a specific type of renewable energy source were excluded from subsequent review.

Results from the 60 focal manuscripts were categorized in contextually specific ways for the simplicity of display and interpretation of data. The renewable energy sources discussed in the focal manuscripts were classified into seven categories following the definitions of the International Energy Agency (IEA) [12]: (i) combustible renewables and waste, (ii) geothermal, (iii) hydrogen, (iv) hydropower, (v) solar, (vi) tide, wave and ocean, and (vii) wind.

Factors impacting the renewable energy deployment decision of countries were also grouped into seven categories: (i) economic, (ii) environmental, (iii) political, (iv) regulatory, (v) social, (vi) technical potential, and (vii) technological. *Economic factors* relate to the changes in national income, capital, labor, prices, and import-export balances. *Environmental factors* include the changes in the natural environment such as CO_2 emissions and air pollution. *Political factors* comprise government policy and governmental practices such as the existence of governmental support for financing renewable energy sources and a nation's electoral system family (majoritarian, combined, or proportional). *Regulatory factors* are the changes directly related to governmental policy including intergovernmental involvements such as EU membership and Kyoto signatory status. *Social factors* include public attitudes, opinions, and interests which can change over time. *Technical potential factors* consist of the changes related to population, land area, rural infrastructure, and renewable energy potential. Finally, *technological factors* embody all technical and operational factors. In addition to these seven main categories, the analysis included the complete set of 239 subcategories (see Appendix A for the complete list of main- and subcategories). The two most frequently referenced subcategories within each category are reported in the results.

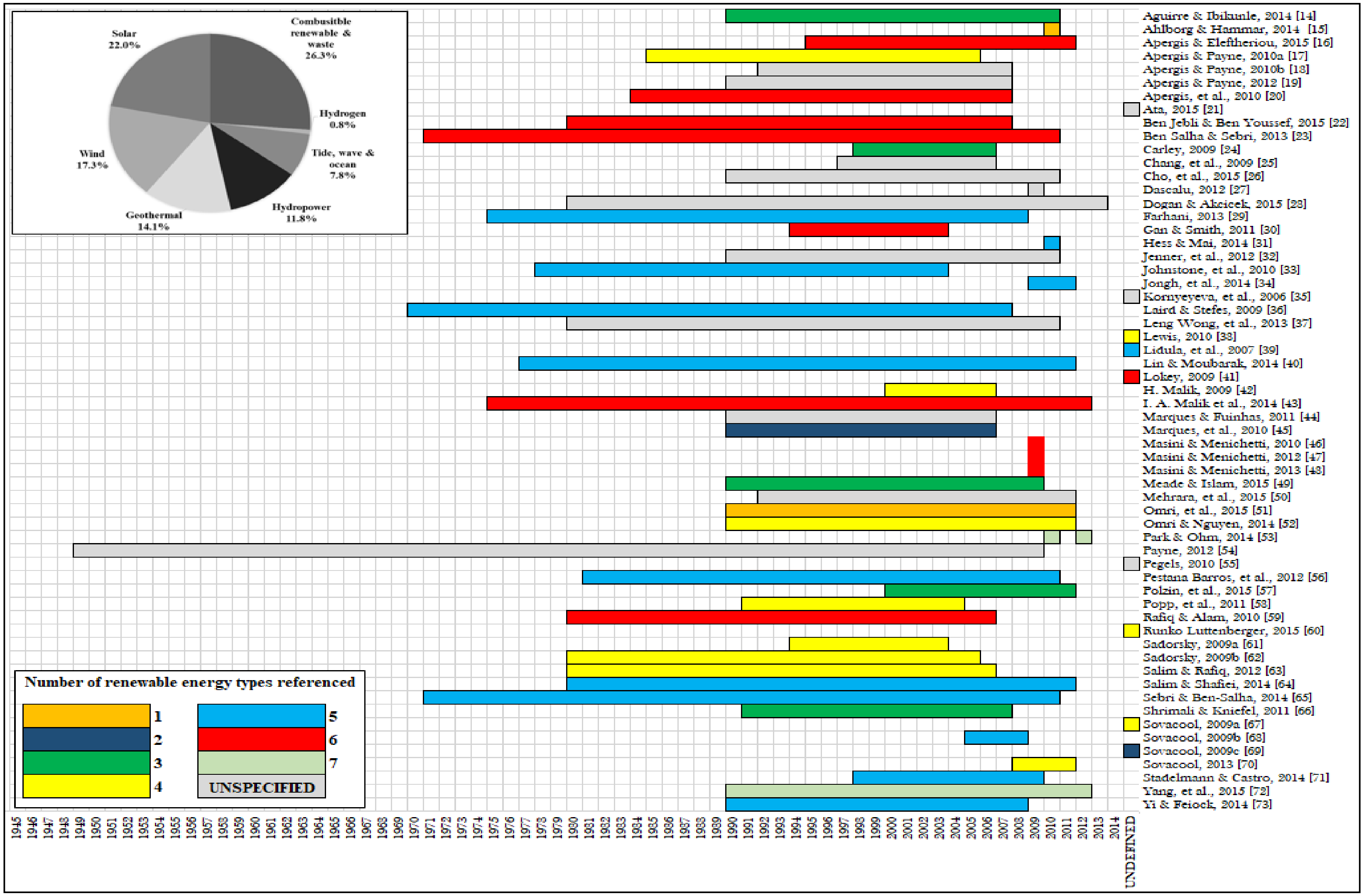
The categories (and subcategories) of the factors impacting the renewable energy deployment decision of countries were classified as either: (i) drivers, (ii) barriers, or (iii) undetermined. Categories in the undetermined classification may be drivers or barriers, but the available information in the focal manuscripts did not lead to either of these direct classifications. To classify the factors, we counted the number of manuscripts that depict a positive (driver) or negative (barrier) relationship between each factor and the renewable deployment decision of countries relative to the total number of manuscripts in the category to obtain the proportion of drivers (or barriers) in each category. Using a one-sample proportion test, if the proportion of manuscripts in a renewable energy deployment category (or subcategory) indicating a positive factor effect was significantly larger than 0.5, the factor was considered a driver. Likewise, using a one sample proportion test, if the proportion of manuscripts in a renewable energy deployment category (or subcategory) indicating a negative factor effect was significantly larger than 0.5, then the factor was considered a barrier. When a category had a low sample size ($n \leq 5$) or if the proportion was not judged to be significantly different from 0.5, the factor was not judged as either a driver or barrier and classified as "undetermined" (see Appendix B for the schematic illustration of one sample proportion test). All tests of significance were conducted using a significance level of 0.05.

3. Results

This systematic literature review includes 41 quantitative and 19 qualitative studies published after 2005. As a result of the PRISMA statement selection process, no manuscript relevant to the current study was published in 2005, when the Kyoto Protocol was put into effect, nor in 2008 when the Kyoto Protocol's first commitment period started. Only two manuscripts were published before 2009, one in 2006 and one in 2007. After 2010, on average, seven manuscripts were published each year, with a maximum number of 13 publications in 2014. These results indicate that countries' decision-making processes on renewable energy deployment gained and retained the attention of scholars after 2008. The increased interest may be explained in several ways. In 2008, in addition to the start date of the Kyoto Protocol's first commitment period, crude oil prices also hit a historical record of $147 per barrel [13]. Volatile prices of traditional energy sources impacted global economies in a negative way and encouraged researchers to consider sustainable energy alternatives that were projected to have more predictable impacts on the economic growth.

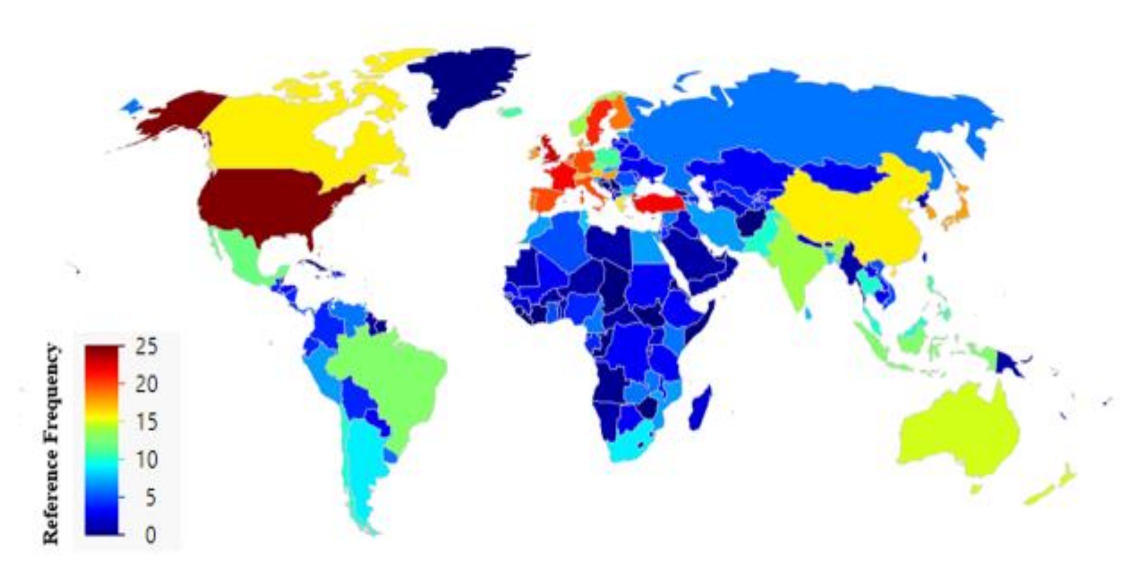
The data considered in the 60 focal manuscripts range from 1949 to 2013. Figure 3 presents both the lengths of studies and the definition of renewable energy by manuscript. Even though countries' decision making processes on renewable energy deployment seemingly gained the attention of scholars beginning after 2008, 25% (n=15) of the focal manuscripts emphasized the 31-year period from 1980 (until 2010). While the years between 1991 and 2007 were studied by 52% (n=31) of the focal manuscripts, the period from 1949 to 1969 was covered by only one manuscript that empirically covered the 61-year period, ending in 2009.

Figure 3: Length of studies by year, number, and type of renewable energy source referenced [14]–[73]



In the 60 focal manuscripts, 147 countries and 11 international organizations were represented, including the Organization for Economic Co-operation and Development (OECD) and the EU (Figure 4). The most frequently referenced regions were North America, Western Europe, Southeastern Asia, and Oceania, whereas, Africa, the Middle East, and Northwestern Asia were the least frequently referenced. The countries that were referenced in 34% (n=20) or more of the focal manuscripts (the United States, the United Kingdom, Turkey, France, Sweden, Spain, Netherlands, Italy, and Germany) were all OECD countries. In the focal manuscripts, 63% (n=92) of the 147 countries were represented only once, whereas 42% (n=25) of the 60 focal manuscripts included the United States, which was the most consistently referenced country.

Figure 4. Countries referenced within the 60 manuscripts



One challenge in comparing the focal studies was that each described renewable energy differently. The renewable energy sources discussed in the focal manuscripts were classified into seven determined categories following the definitions of the IEA [12]: (i) combustible renewables and waste, (ii) geothermal, (iii) hydrogen, (iv) hydropower, (v) solar, (vi) tide, wave and ocean, and (vii) wind. Only 3% (n=2) of the focal manuscripts included all renewable energy source types, whereas 55% (n=33) of the manuscripts included five or fewer renewable energy source types in their studies. One manuscript strictly focused on just one type of renewable energy source: combustible renewables and waste. Lastly, the authors of 23% (n=14) of the focal manuscripts did not provide a specific description of the renewable energy sources which were considered within the original research. The outcomes of these 14 manuscripts were used in the current study because the objective is to provide an overall picture of the drivers and barriers of the renewable energy sources.

The percentage distribution of the renewable energy types that were the focus of the focal manuscripts is presented in Figure 3. The most pervasive definition for renewable energy was combustible renewables and waste, referenced in 26% (n=16) of the focal manuscripts. Solar (22%, n=13) and wind (17%, n=10) energies were also frequently referenced within the focal manuscripts. The large number of manuscripts focusing on combustible renewables and waste compared to the other renewable energy types may be explained by the availability of data. The data on electricity generation from renewable energy sources was recorded beginning in 1980 by the United States Energy Information Administration (EIA). While data on combustible renewables and waste has been available since 1980, the data on wind and solar energies were only reported beginning in 1986 and 1989, respectively. These three sources of energy (combustible renewables and waste, solar and wind) were also the renewable energy types that have shown the most consistent and highest growth over the years based on longitudinal data provided by the EIA [74]. Among the focal manuscripts, hydrogen was the least referenced renewable energy source, appearing in only 3% (n=2) of the focal manuscripts. Hydrogen is also the only renewable energy source which has not been recorded by the EIA. Each of the remaining renewable energy sources was referenced by at least 8% (n=5) of the focal manuscripts.

There were 489 different factors identified in the focal manuscripts that explain the diverging paths of countries' decisions on renewable energy deployment. In the current study, we classified these factors into seven categories: (i) economic, (ii) environmental, (iii) political, (iv) regulatory, (v) social, (vi) technical potential, and (vii) technological. In addition to these seven main categories, this study defined 239 subcategories (see Appendix A for the complete list of main- and subcategories). The most prevalent factors were economic and regulatory in nature, with each being referenced more than 100 times in the focal manuscripts (138 and 106 times, respectively), whereas environmental factors were the least frequently referenced (18 times). Renewable energy technologies were relatively new and remain expensive [75]. Accordingly, it was not surprising that at least one economic variable was included in 58 (97%) of the focal manuscripts to explain the impact of economic factors on the renewable energy deployment decision of countries. Another possible explanation for this emphasis on economic factors might be associated with the prevalent use of secondary data by the vast majority (90%, n=54) of the papers considered. Excluding six (10%) of the focal studies which use survey data, all manuscripts utilized secondary data collected and made available from reputable sources such as the

IEA and the EIA. Economic growth has been the focus of scholars since the Industrial Revolution, whereas social and environmental pillars of sustainability gained increasing attention only after the Rio Declaration on Environment and Development in 1992 [76]. As a result, data for the economic variables were usually more accessible and frequently used, while data for the environmental factors were recent and limited, and therefore used less frequently.

Table 1 summarizes the frequency with which the focal manuscripts emphasized each of the seven categories as drivers or barriers. In addition to the seven main categories, two primary subcategories within each factor were included in the table.

Out of seven main categories, economic, environmental and social factors were the only ones that were considered drivers. The impacts of political, regulatory, technical potential and technological factors were considered undetermined. Only one subcategory – *national income* – was found to be a driver. All remaining subcategories were found to have undetermined impacts due to: (i) the small number of manuscripts considering these factors either as drivers or barriers (i.e., *air pollution, democracy, representation of green party, Kyoto status, public confidence in technological measures, public interest in renewables, land area of countries, operating experience, and R&D expenditures on renewables*), and/or (ii) the lack of statistically significant positive or negative impacts on the renewable energy deployment of countries (i.e., *price of non-renewables*, *CO_2 emissions, subsidies and renewable energy potential*). None of the main categories or subcategories were found to be a barrier.

Table 1: Factors explaining the diverging paths of renewable energy decisions

Factors	**Classification (Driver/ Barrier/ Undetermined)**	**Positive impact (# of studies)**	**Negative impact (# of studies)**
(i) Economic	**Driver**	**82**	**47**
National income	Driver	27	9
Price of non-renewables	Undetermined	12	9
(ii) Environmental	**Driver**	**11**	**4**
CO_2 emissions	Undetermined	10	4
Air pollution	Undetermined	1	0
(iii)Political	**Undetermined**	**20**	**15**
Democracy	Undetermined	3	1
Representation of green party	Undetermined	1	1
(iv)Regulatory	**Undetermined**	**53**	**47**
Subsidies	Undetermined	4	2
Kyoto status	Undetermined	3	0
(v) Social	**Driver**	**25**	**14**
Public confidence in technological measures	Undetermined	3	0
Public interest on renewables	Undetermined	2	0
(vi)Technical potential	**Undetermined**	**32**	**44**
Land area of countries	Undetermined	4	0
Renewable energy potentials	Undetermined	8	7
(vii) Technological	**Undetermined**	**25**	**29**
Operating experience	Undetermined	4	0
R&D expenditures on renewables	Undetermined	3	0

It was expected that the renewable energy deployment levels would increase with better economic indicators. *National income*, an important indicator of a strong economy, was found to be the only significant driver within this category. Similarly, renewable energy deployment levels would be expected to increase with the *price of non-renewable energy sources*, since renewable and non-renewable energy sources were economic substitutes of one another. However, the price of non-renewable energy source subcategory was found to be a driver in 12 studies and a barrier in nine studies, and, overall, was classified as a factor that has an undetermined impact on the renewable energy deployment of countries.

Environmental factors tend to be drivers. Within this category, focal manuscripts considered only air emissions. *Air pollution* was studied once and CO_2 *emissions* were studied 16 times. As a result of the one sample proportion test, the impact of CO_2 *emissions* was found to be undetermined, due to the 29% (n=4) of the studies arguing that these emissions could actually have a negative impact.

The existing literature found social considerations to be drivers for renewable energy deployment. However, no subcategories within this category were found to have a statistically significant impact on the countries' renewable energy deployment decisions. Within the existing literature, none of these factors were considered more than five times, preventing us from calling them either drivers or barriers.

All remaining categories and their subcategories (81%, n=17) presented in Table 1 were found to have undetermined impacts on our research focus. For eight (38%) of the categories and subcategories presented in Table 1 (four main categories and four subcategories), there was a lack of statistical significance to conclude that these factors as either drivers or barriers. The remaining nine (43%) subcategories from Table 1 were underrepresented in the literature because none of them were analyzed more than five times within the focal manuscripts. Including the subcategories from Appendix A, the proportion of the underrepresented factors goes up to 95% (n=227) of all subcategories (n=239) analyzed by the focal manuscripts.

The underrepresentation of the factors significantly impacts the overall results. For instance, the only technological subcategories used more than twice in the focal studies were the experience of the renewable energy project investors (*operating experience*) and *research and development expenditures on renewables* which influence the renewable energy deployment of countries only in a positive way. As a result of the lack of representation of these factors within the existing literature, we are unable to interpret these factors as drivers. Underrepresentation of the majority of the factors (95% of the subcategories) used in the existing literature to explain the renewable energy deployment of countries remains an issue that deserves attention for further research.

4. Discussion and conclusion

This systematic literature review, which includes 60 manuscripts identified using a multistage selection process, contributes to the discourse on the factors (drivers and barriers) necessary to explain the diverging paths of renewable energy deployment for countries. The literature examined in this study contains three main deficiencies: (i) the results from this study suggest several areas of over – and underrepresentation (there is not an equal representation of countries represented, periods analyzed and factors focused on by the manuscripts), (ii) renewable energy deployment, the dependent variable, was not consistently defined within the manuscripts, and (iii) the types of renewable energy sources considered varied between the manuscripts.

The results from this study suggest several areas of over – and underrepresentation. The first over- and underrepresentation problem emerges for the country-set focused on within the existing literature. Out of 147 countries and 11 international organizations represented in the focal manuscripts, the United States, the United Kingdom, Turkey, France, Sweden, Spain, Netherlands, Italy, and Germany (all nine countries are OECD members) were referenced in 34% (n=20) or more of the manuscripts while 62% (n=92) of the countries were represented only once. The existing literature consists of 41 quantitative and 19 qualitative studies among which only 17% (n=10) uses primary (survey) data. All remaining manuscripts (83%, n=50) use readily available secondary data, which is primarily available for “high income” countries. As a result of insufficient infrastructure and a restricted budget, low and middle-income countries have limited data availability. To include further information from these countries, an increased number of field studies focusing on characteristics of renewable energy deployment at the local and regional levels need to be conducted.

The period between 1991 and 2007 is overrepresented since the majority of the manuscripts (52%, n=31) cover that period while there are fewer studies before 1980 and after 2010. There is only one study covering the years between 1949 and 1969. The underrepresentation of the period after 2010 may be related to the availability of the existing data due to the time lag required to collect and analyze data. Future studies will have access to more recent data and this issue should be easily to overcome, as long as data continue to be collected. A recommendation to scholars who have already contributed or plan to contribute to this newly emerging branch of interdisciplinary studies would be to constitute an open access data source for the use of other researchers. Accessible and comprehensive data sets will lead to stronger research.

The 489 factors addressed by the focal manuscripts were classified into seven main categories. Among these categories, economic factors were noticeably overrepresented (referenced 138 times), whereas environmental factors were underrepresented (referenced only 18 times). Likewise, it was observed that 58 (97%) of the focal manuscripts included at least one economic variable to explain the renewable energy deployment of countries, and six (10%) of the manuscripts referenced only economic considerations to explain countries' renewable energy deployment decisions. However, economic factors were not found to be the only driver that encourages the renewable energy deployment, but factors from all three pillars of sustainability (economic, environmental and social). Therefore, environmental and social factors also deserve closer attention for future research. For instance, only air emissions were used within the category of environmental factors. Renewable energy sources have additional benefits such as a reduced water footprint and lower wastewater and solid waste pollution [77], which have not been considered. In order to overcome the underrepresentation problem of factors addressed in the literature, there is a need to both increase the number of environmental and social factors and focus on the existing - but inadequately represented– subcategories (such as air pollution and public confidence measures).

Similarly, we also observed that publication bias in favor of drivers may exist in the literature. This tendency may be because the renewable energy sources are currently viewed as tools to reduce CO_2 emissions, mitigate climate change, and thus save the planet. As a result, authors may present interesting results that are useful for the promotion of renewable energy deployment and for policy-making. Focusing on barriers to renewable energy source deployment would remain descriptive, whereas focusing on drivers would be prescriptive [78], and so barriers of renewable energy deployment are underrepresented in the focal manuscripts. Future studies should address potential barriers along with the drivers of the deployment for a systematic examination of renewable energy deployment.

Renewable energy deployment, which was selected as the dependent variable in our work, was not consistently defined. Out of 60 studies, 27 (45%) focused on renewable energy consumption, 27 (45%) on renewable energy potential, and the remaining six (10%) discussed either renewable energy targets, renewable energy policies of nations, or renewable energy deployment in general. Due to the limited number of manuscripts published prior to 2009, this literature review incorporates both quantitative and qualitative studies with five different renewable energy deployment definitions. Combining both quantitative and qualitative studies, we were able to consider a larger number of underrepresented factors, especially those specific to qualitative studies (i.e., *public confidence to the renewables*). Moreover, by including six studies using survey data, we were able to incorporate several measures which would not be easily available for researchers using secondary data (i.e., *investor's experience in the field*). In bringing together these studies, our objective was to eliminate the underrepresentation of the major factors (i.e., economic and social factors). In the future, we expect that more qualitative studies will be added to the literature and, thus, the number of underrepresented factors will be decreased. In addition, combining different renewable energy deployment definitions allowed us to increase the level of representation of the factors affecting the renewable energy decisions of countries. Following the addition of further academic studies to the field, we suggest future researchers to investigate all five renewable energy deployment definitions separately (i.e., consumption, energy potential, targets, policies of nations, or deployment in general).

The last challenge in comparing the focal manuscripts was the number of studies within each of the seven categories of renewable energy sources, as well as the number of renewable energy sources considered within one study. Among these categories, combustible renewables and waste, solar and wind were represented in 65% (n=39) of the studies, whereas hydrogen appeared in only 3% (n=2) of them. One manuscript focused on one type of renewable energy source (combustible renewables and waste), while two manuscripts included all seven renewable energy sources. In addition to these issues, 23% (n=14) of the manuscripts did not provide a specific "renewable energy" definition. The outcomes of these 14 manuscripts were used in the current study because the objective of the current study was to provide an overall picture of the drivers and barriers of the renewable energy deployment decisions. Nevertheless, it is important for all scholars to clearly describe the input included in their research. Comparisons of outcomes of studies that omit the specific description of inputs, such as renewable energy sources considered in the original research, becomes challenging.

Overall, the limitations of the current literature on diverging paths of renewable energy deployment for countries requires future research to seek to minimize the overrepresentation and the underrepresentation factors in such study. Moreover, the use of a unique dependent variable definition and clearly defined sets of renewable energy source types will increase the ability to understand both the drivers and barriers of renewable energy deployment, beyond economic extent.

Appendix A. Full list of factors explaining the diverging paths of renewable energy decisions[i,ii]

Factors	Classification (Driver/ Barrier/ Undetermined)	Positive impact (Number of studies)	Negative impact (Number of studies)	Undetermined impact (Number of studies)	Total number of studies
Economic	**Driver**	**82**	**47**	**9**	**138**
Capital	Undetermined	1	0	0	1
Consumer price index of energy	Undetermined	1	1	0	2
Cost of RETs	Undetermined	2	2	0	4
Demand increase	Undetermined	1	0	0	1
Domestic credit (% of GDP)	Undetermined	1	0	0	1
Economic effect	Undetermined	1	0	0	1
Economic growth	Undetermined	3	2	0	5
Exchange rate	Undetermined	0	1	0	1
Financial assistance	Undetermined	1	0	0	1
Financial viability of RETs	Undetermined	1	3	0	4
Foreign Direct Investment inflow level	Undetermined	1	0	0	1
Gross Capital Formation	Undetermined	2	0	0	2
Gross Fixed Capital Formation	Undetermined	4	0	0	4
Growth of non-renewables price	Undetermined	0	1	0	1
Import export balances	Undetermined	2	0	2	4
Income generation	Undetermined	1	0	0	1

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[i] RE: Renewable Energy; RETs: Renewable Energy Technologies, R&D: Research and Development

[ii] Factors in bold are also represented in Table 1.

Inflation	Undetermined	1	1	0	2
Interest rates	Undetermined	0	1	0	1
Labor	Undetermined	5	0	1	6
Labor employed in natural resources sector (per 1000 capita)	Undetermined	1	0	0	1
Lack of financial institutions	Undetermined	0	1	0	1
Lack of funds	Undetermined	0	2	1	3
Local entrepreneurship	Undetermined	1	0	0	1
Market imperfections	Undetermined	1	4	1	6
Market power of renewables	Undetermined	1	0	0	1
Market power of utilities	Undetermined	0	1	0	1
Marketing	Undetermined	1	0	0	1
National income	**Driver**	**27**	**9**	**1**	**37**
Price of electricity	Undetermined	4	3	1	8
Price of non-renewables	**Undetermined**	**12**	**10**	**1**	**23**
Private attention to renewable energy	Undetermined	0	0	1	1
Risks and costs of RETs	Undetermined	0	1	0	1
Share of industry in national income	Undetermined	1	1	0	2
Share of non-renewables in national income	Undetermined	0	1	0	1
Share of service in national income	Undetermined	1	0	0	1
Tax index	Undetermined	0	1	0	1
Trade openness	Undetermined	4	0	0	4
US Central Appalachian coal spot price index growth	Undetermined	0	1	0	1

Environmental	**Driver**	**11**	**4**	**3**	**18**
CO_2 emissions	Undetermined	10	4	2	**16**
Air pollution	Undetermined	1	0	0	**1**
Environment	Undetermined	0	0	1	1
Political	**Undetermined**	**20**	**15**	**6**	**41**
Bureaucracy	Undetermined	0	1	0	1
Citizens' political ideology	Undetermined	0	0	2	2
Continuous commitment	Undetermined	1	0	0	1
Corruption	Undetermined	0	0	1	1
Degree of legal system	Undetermined	1	0	0	1
Democracy	**Undetermined**	**3**	**1**	**0**	**4**
Donor dependency	Undetermined	0	1	0	1
Donor push/support	Undetermined	1	0	0	1
Government effectiveness	Undetermined	1	0	0	1
House of Representative pro-environment score	Undetermined	2	0	0	2
Institutional creation	Undetermined	0	1	0	1
Interest groups	Undetermined	0	1	0	1
Lack of governmental support	Undetermined	0	2	0	2
Legislative Professionalism	Undetermined	1	0	0	1
Number of legislative parties	Undetermined	1	0	0	1
Political climate	Undetermined	1	0	0	1
Political instability	Undetermined	0	1	0	1
Political involvement	Undetermined	0	1	0	1
Political election campaigns	Undetermined	1	0	0	1

Power of interest groups (conventional energy sources)	Undetermined	0	1	1	2
Public Utilities' Governance	Undetermined	0	2	0	2
Public Utilities' Professionalism	Undetermined	1	0	0	1
Representation of green party	**Undetermined**	**1**	**1**	**1**	**3**
Rule of law	Undetermined	1	0	0	1
Size of the government	Undetermined	0	1	0	1
State-run electric utility	Undetermined	0	1	0	1
State's electoral family	Undetermined	1	0	0	1
Strategic planning	Undetermined	1	0	0	1
Support from political actors	Undetermined	0	1	1	2
Veto players	Undetermined	0	1	0	1
Regulatory	**Undetermined**	**53**	**47**	**6**	**106**
Capacity building measures	Undetermined	1	0	0	1
CEFTA membership	Undetermined	1	0	0	1
Clean Development Mechanism	Undetermined	1	0	1	2
Clean energy fund	Undetermined	1	0	0	1
Codes and standards	Undetermined	1	0	0	1
Common colony	Undetermined	0	1	0	1
Compensations (for land acquisitions)	Undetermined	0	1	0	1
Deregulation of energy markets	Undetermined	1	1	0	2
Direct investment	Undetermined	1	1	0	2
Emission cap and trade	Undetermined	0	1	0	1
Environmental Impact Directive	Undetermined	0	1	0	1
EU directives	Undetermined	1	0	0	1

EU membership	Undetermined	2	0	1	3
Extent of regulatory restraints	Undetermined	0	1	0	1
Feed-in tariff	Undetermined	3	2	0	5
Fiscal support	Undetermined	3	4	0	7
Funds to subnational governments	Undetermined	0	1	0	1
GHG allowances	Undetermined	1	0	0	1
Global Environment Facility (GEF) funding	Undetermined	1	0	0	1
Global promotion of RE	Undetermined	1	0	0	1
Governmental policies	Undetermined	1	0	0	1
Green certificates	Undetermined	0	2	0	2
Green power policy options	Undetermined	1	0	0	1
Guaranteed price	Undetermined	0	1	0	1
Inadequate planning capacity	Undetermined	0	1	0	1
Incompatible donor policies	Undetermined	0	1	0	1
Increased competition measures	Undetermined	0	0	1	1
Institutional influence of outside consultants	Undetermined	1	1	0	2
Institutional influence of peers	Undetermined	0	2	0	2
International development aid	Undetermined	0	1	0	1
Investment incentives	Undetermined	1	0	0	1
Kyoto status	**Undetermined**	**3**	**0**	**0**	**3**
Lack of co-investments	Undetermined	0	1	0	1
Lack of market infrastructure	Undetermined	0	1	0	1
Lack of organizational capacity	Undetermined	0	1	0	1

Lack of private sector involvement	Undetermined	0	1	0	1
Lack of regulatory measures	Undetermined	0	1	0	1
Legislation issues in connecting RE to national grid	Undetermined	0	1	0	1
Limited policy framework	Undetermined	0	1	0	1
Loans	Undetermined	1	1	0	2
Local regulatory initiatives	Undetermined	1	0	0	1
Low institutional quality	Undetermined	0	1	0	1
Mandatory requirements	Undetermined	1	0	0	1
Market based instruments	Undetermined	3	0	0	3
Negotiated agreements	Undetermined	1	0	0	1
Neighbors	Undetermined	1	0	0	1
Net metering	Undetermined	0	1	0	1
New legislation	Undetermined	1	0	0	1
Non-ecological subsidies	Undetermined	0	1	0	1
Obligations (policy proxy)	Undetermined	2	0	0	2
Organizational professionalism	Undetermined	0	0	1	1
Policy time period	Undetermined	1	0	0	1
Price-driven policies	Undetermined	1	0	0	1
Programmatic flexibility	Undetermined	1	0	0	1
Pro-poor policies	Undetermined	1	0	0	1
Public benefit funds	Undetermined	0	1	0	1
Quantity-driven policies	Undetermined	0	0	1	1
Regional Energy Association funds	Undetermined	1	0	0	1
Regulations of interest groups	Undetermined	0	0	1	1

Regulatory instruments	Undetermined	1	0	0	1
Regulatory quality	Undetermined	1	0	0	1
Renewable Energy Certificate imports	Undetermined	0	1	0	1
RE consumption targets	Undetermined	1	0	0	1
Renewable Portfolio Standards	Undetermined	3	4	0	7
Required green power option	Undetermined	1	0	0	1
Research and innovation policies	Undetermined	0	1	0	1
State green power purchase requirement	Undetermined	0	1	0	1
Subsidies	**Undetermined**	**4**	**2**	**0**	**6**
Top-down management in energy-sector	Undetermined	0	1	0	1
Voluntary instruments	Undetermined	0	2	0	2
Social	**Driver**	**25**	**14**	**5**	**44**
Attitude toward radical technological innovations	Undetermined	0	1	0	1
Behavioral impediments	Undetermined	0	1	1	2
Cognitive capabilities	Undetermined	1	0	0	1
Community ownership	Undetermined	1	0	0	1
Confidence in market efficiency	Undetermined	1	0	1	2
Confidence in policy effectiveness	Undetermined	2	0	0	2
Confidence in technological measures	**Undetermined**	**3**	**0**	**0**	**3**
Cultural barriers	Undetermined	0	3	0	3
Education	Undetermined	3	0	0	3
Expectations of public from RETs	Undetermined	0	0	1	1
Gender issues	Undetermined	0	1	0	1

GINI coefficient	Undetermined	1	0	0	1
Instability of public support	Undetermined	0	1	0	1
Knowledge of RETs	Undetermined	2	0	0	2
Lack of knowledge on RETs	Undetermined	0	1	0	1
Lack of local engagement	Undetermined	0	2	0	2
Long memory behavior	Undetermined	1	0	0	1
Perceived importance of governmental support	Undetermined	1	1	0	2
Perceived importance of RE policies	Undetermined	1	0	0	1
Perceived risks and benefits of RETs	Undetermined	1	0	0	1
Poverty	Undetermined	0	1	0	1
Public interest on RE	**Undetermined**	**2**	**0**	**2**	**4**
Public opposition	Undetermined	0	1	0	1
Social trust	Undetermined	1	0	0	1
Stakeholder engagement	Undetermined	2	0	0	2
Unemployment rate	Undetermined	2	0	0	2
Weak local management culture	Undetermined	0	1	0	1
Technical potential	**Undetermined**	**32**	**44**	**9**	**85**
Area (land area of country)	**Undetermined**	**4**	**0**	**0**	**4**
Energy consumption (non-renewable)	Undetermined	1	0	0	1
Energy consumption (nuclear)	Undetermined	0	1	0	1
Energy consumption (RE)	Undetermined	1	0	0	1
Energy consumption (total)	Undetermined	3	2	1	6
Energy consumption growth	Undetermined	0	2	0	2
Energy dependency	Undetermined	0	2	0	2

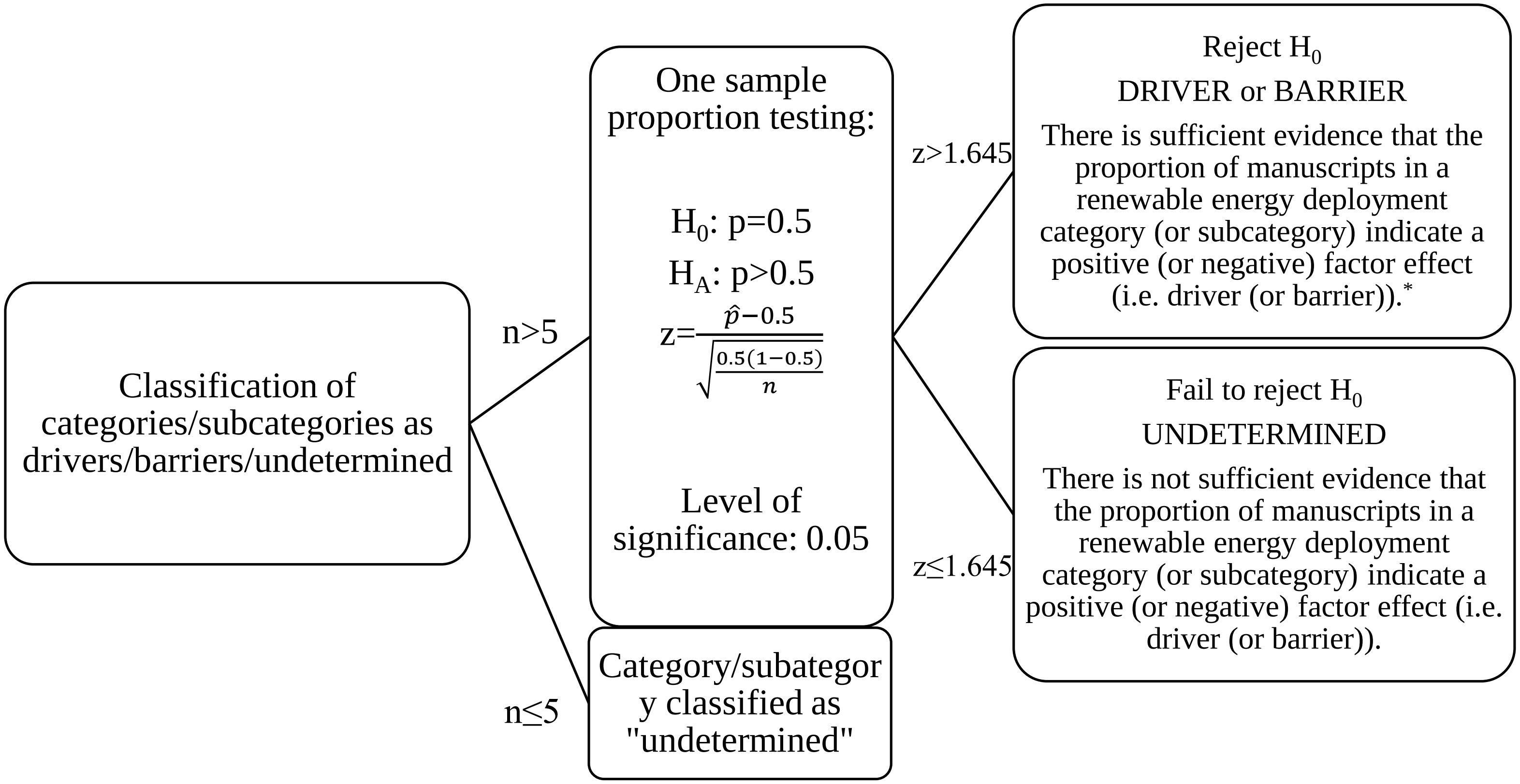
Energy production (coal)	Undetermined	0	3	0	3
Energy production (gas)	Undetermined	0	3	0	3
Energy production (nuclear)	Undetermined	0	4	1	5
Energy production (oil)	Undetermined	0	3	0	3
Energy production (RE)	Undetermined	0	1	1	2
Energy production (total)	Undetermined	0	0	1	1
Energy security	Undetermined	1	1	1	3
Export status	Undetermined	1	0	0	1
Food Production Index	Undetermined	0	1	0	1
Historical/traditional factors	Undetermined	1	1	0	2
Import dependency	Undetermined	3	1	0	4
Latitude	Undetermined	0	1	0	1
Neighbor effect	Undetermined	1	0	0	1
Non-renewable energy potential	Undetermined	0	0	2	2
Population	Undetermined	3	1	2	6
Population density	Undetermined	1	2	0	3
Population growth	Undetermined	1	2	1	4
RE potentials	**Undetermined**	**8**	**7**	**0**	**15**
Rural Infrastructure	Undetermined	1	3	0	4
Urbanization	Undetermined	2	2	0	4
Technological	**Undetermined**	**25**	**29**	**3**	**57**
Appropriate technology	Undetermined	1	0	0	1
Carbon intensity (of existing technologies)	Undetermined	0	1	0	1

Commercial attitudes towards R&D investments	Undetermined	0	0	1	1
Construction lead time	Undetermined	1	0	0	1
Effective load carrying capability	Undetermined	1	0	0	1
Efficiency or quality concerns of RE	Undetermined	0	1	0	1
Electricity generation capacity from RE	Undetermined	0	2	0	2
Electricity consumption per capita	Undetermined	0	1	0	1
Electricity distribution losses	Undetermined	0	1	1	2
Electricity installation	Undetermined	0	0	1	1
Energy intensity	Undetermined	0	1	0	1
Energy mix effect	Undetermined	1	0	0	1
Factor endowment in conventional energy sources	Undetermined	1	0	0	1
Grid-extension requirement	Undetermined	1	0	0	1
High pre-installed capacity based on conventional energy sources	Undetermined	0	1	0	1
Improved capacity factors	Undetermined	1	0	0	1
Inadequate data and information	Undetermined	0	1	0	1
Inappropriate distribution facilities	Undetermined	0	1	0	1
Industrialization	Undetermined	0	1	0	1
Industry installing their own power systems	Undetermined	1	0	0	1
Influence of existing technical experience (on conventional energy sources)	Undetermined	0	2	0	2
Investor's experience	**Undetermined**	**4**	**0**	**0**	**4**

Knowledge of the RE operational context	Undetermined	1	0	0	1
Lack of back-up systems	Undetermined	0	1	0	1
Lack of consistency between RE projects	Undetermined	0	1	0	1
Lack of experience and awareness in RE technologies and management	Undetermined	0	1	0	1
Lack of research personal or trained manpower	Undetermined	0	2	0	2
Level of access to required materials	Undetermined	0	1	0	1
Level of unplanned outages	Undetermined	1	0	0	1
Limited rural infrastructure (roads etc.)	Undetermined	0	1	0	1
Long-distance transmission needs	Undetermined	0	1	0	1
Low production capacity of existing RE technologies	Undetermined	0	2	0	2
Need of increased sustainability on grid	Undetermined	1	0	0	1
Number of RE policies and measures on technological R&D on RE	Undetermined	0	1	0	1
Productive local electricity uses	Undetermined	1	0	0	1
Proportion of RE to energy supply	Undetermined	1	1	0	2
R&D expenditures in conventional energy sources	Undetermined	0	1	0	1
R&D expenditures on RE	**Undetermined**	**3**	**0**	**0**	**3**
Spatial diversification	Undetermined	1	0	0	1
Technical standardization	Undetermined	1	0	0	1
Technological path dependency	Undetermined	1	1	0	2

Technological push	Undetermined	1	0	0	1
Technological risk attitudes of investors	Undetermined	0	2	0	2
Total EPO (European Patent Office) fillings	Undetermined	1	0	0	1

Appendix B. One Sample Proportion Test[i,ii]



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[i] One sample proportion test conducted separately for positive and negative factor effects.

[ii] n: number of manuscripts indicating both positive and negative factor effect in a renewable energy deployment category/subcategory p: proportion of the manuscripts indicating a positive or negative factor effect

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CHAPTER THREE

ECONOMIC AND ENVIRONMENTAL FACTORS OF WIND ENERGY DEPLOYMENT IN THE UNITED STATES

Abstract

Among the most promising clean energy sources in the electricity market, wind energy has substantially increased its share in the global energy portfolio. Since 2000, the United States has led the world in newly installed generation capacity per capita. The current study explores the determinants of this growth and, using a fixed-effects panel data regression analysis, investigates the significance of a number of economic and environmental factors on the wind energy deployment in the United States between 2000 and 2015. Economic factors include gross state product, the value of agricultural sector, and the unemployment rate; environmental factors include carbon dioxide emissions, nitrogen oxide emissions, and water use. The empirical findings provide strong evidence that in the United States, an increase in economic factors is related to a significant increase in the installed wind energy capacity, whereas, the increase in environmental factors is related to a significant decrease in the installed wind capacity. These findings are expected to contribute to the understanding of how states might best stimulate and support wind energy deployment.

1. Introduction

Wind has been supplying power to humanity for more than 3500 years [1]. Over the last 15 years, wind energy has substantially increased its share in the global energy portfolio, primarily due to its extensive availability as well as the low operating costs of wind turbines [2]. Since 2000, the average increase in the global wind energy generation capacity has been 23.2% annually [3]. For the same period, the United States (U.S.) has experienced the fastest growth in the global wind power industry and extended its wind energy generation capacity by 24.3% on average annually [4] [5].

The objective of the current study is to more closely examine the determinants of the U.S. wind energy growth. Using a fixed-effects panel data regression analysis, we investigate the dynamic relationship between the increase in wind energy generation capacity and a number of economic and environmental factors in 39 U.S.[i] states from 2000 to 2015.

Among economic and environmental factors, economic considerations were often used in the renewable energy deployment literature of countries. Apergis and Payne (2012), Chang et al. (2009), Dascalu (2012), Omri and Nguyen (2014) and Sadorsky (2009) revealed that economic factors have a positive relationship with countries' renewable energy deployment decisions [6]–[10]. National income was the most frequently studied economic factor. The level of national income found to be associated with an increased renewable energy deployment in a multitude of studies [11]–[16]. Likewise, Dascalu (2012) and Jenner et al. (2012) investigated the relationship between unemployment rate,

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[i] Only states with existing wind generation capacity are taken into consideration.

which is considered another important—yet underrepresented—economic factor, and renewable energy deployment [7], [17]. Both scholars concluded that the increase in the unemployment rate was related to an increase in renewable energy deployment [7], [17].

Even though the existing literature of renewable energy provides a general outlook of the factors of wind power deployment, there is a need to include wind energy specific data and terms to the analysis to understand how states may best stimulate and support the increase in wind power generation capacities. Much of the literature in this area is focused on renewable energy sources in general, instead of particular renewable sources of energy, and the literature on the factors that are associated with wind energy deployment is limited.

The current literature on the wind power deployment includes only a few studies that have investigated the relationship between economic factors and wind energy deployment. The quantitative analysis of Bird et al. (2005) concluded that improved economic conditions (e.g., higher income levels and a developing market for green power) were associated with an increase in the installed wind capacities in 12 United States (U.S.) states [18]. Ewing et al. (2007) empirically investigated the significance of economics (industrial production) on wind power (among other renewable and non-renewable energy sources) in the U.S. and revealed that between 2001 and 2005, an increased level of industrial production was associated with a decrease in wind energy deployment [19].

Economic factors that will be considered in the current study include state income (gross state product), the unemployment rate, and the contribution of the agricultural sector to the national economy. Higher income levels allow countries (or states) to bear the cost of renewable energy technologies and regulatory policies [20]. Therefore, in the current study, we expect that the gross state product per capita (as a proxy for the state income level) and state's installed wind energy capacity have a positive relationship. Similarly, the unemployment rate is expected to be related to an increase in wind power sourced electricity deployment because, being an emerging industry, wind energy is expected to create new jobs in the United States.

The role of agricultural income has not yet been considered in the current literature on the deployment of renewable energy. Wind-powered electricity generation involves a significant amount of land and wind farms are mainly located on agricultural lands [21]. Leasing their land for wind power offers a new source of income for farmers and ranchers. The current study, therefore, suggests that there is a relationship between the income of the agricultural sector and the increase in wind energy generation capacities. But there are only a few studies that consider the relationship between the agricultural sector and the wind energy deployment. Adelaja and Hailu (2008) investigated the unidirectional relationship between wind energy development and agricultural viability in Michigan (U.S) [21]. The focus of the study was the indirect threat posed by the alternatives income resources (e.g., lease payments) on the U.S. food security [21]. Scholars suggested that the increased income alternatives for land owners might negatively impact the agricultural production and the decreased level of agricultural production might threaten the food supply [21]. Their findings revealed different impact distribution in different Michigan counties and they suggested that cross-sectorial relationships needed to be further investigated as wind energy deployment becomes more land intensive [21]. Similarly, the meteorological impacts of wind turbines on the agricultural production was studied by Rajewski et al.

(2013) [22]. Their findings revealed that wind farms were expected to have positive impacts on croplands (e.g., affecting variables such as temperature and carbon dioxide (CO_2) concentrations in favor of the crops) through the air turbulence that wind turbines create [22]. The contribution of wind energy turbines on the agricultural sector was also reported by a study conducted by Mills in 2016 [23]. In her study, Mills (2016) surveyed more than 1200 farm landowners in Michigan and concluded that wind power provides a steady income for farmers and ranchers and, therefore, had a significant and positive outcome in the agricultural sector [23]. In the current study, we expect that the wind power deployment increases as the income level in the agricultural sector increases due to the lease payments of wind turbines and positive impact of wind farms on croplands.

Environmental concerns are suggested to be the drivers for the widespread use of all renewable energy sources [20]. Nevertheless, the renewable energy deployment literature that focused on environmental factors was limited and mainly considered CO_2 emissions [8], [15], [24]–[26]. Increased CO_2 emissions were found to be associated with an increase in the renewable energy deployment of countries in the majority of the studies [6], [16], [17], [19]. Similar to the renewable energy deployment literature, the literature on the wind energy deployment has not often considered the environmental factors. The damage from wind farms to wildlife was the main focus of the investigation into the relationship between the environment and wind energy deployment [28], [29]. The current literature on renewable energy and wind energy deployment neglected other environmental benefits, such as a reduced water footprint and lower air emissions, such as nitrogen oxide (NO_X) or sulfur dioxide (SO_2) emissions [28].

The current study includes both CO_2 and NO_X emissions because wind power is power is expected to play an important role in environmental pollution prevention. Wind power technologies are considered green technologies because the impact on the environment is minor compared to non-renewable energy options [30]. The energy payback time, which correspond to how long the wind power plant needs to produce energy to compensate for the energy required from manufacturing wind turbines and construction of wind farm is paid back only a few months [28]. Similarly, wind turbines do not produce air pollutants (such as CO_2, SO_2, and NO_X) during power generation as conventional sources of energy do [31] and the air emissions that are released during the construction and maintenance of wind power plants are negligible [30]. In the Wind Vision initiative, the U.S. Department of Energy (US–DOE) defines the contributions of wind power to the future electricity needs of the nations as follows: (i) reduced carbon emissions, (ii) improved air quality, and (iii) reduced water use [32].

According to the U.S. Energy Information Administration (US-EIA), natural gas, coal and nuclear were the largest three energy sources in the U.S. in 2016, producing 84% of the total electricity generated [33]. In the U.S., wind energy produced only 5.6% of the electricity generated in 2016 [3]. Nevertheless, the pollution created by wind energy turbines is noticeably lower than thermal power plants, which rely on the combustion of conventional sources such as natural gas and coal. Compared to the combustion of natural gas, CO_2 emissions are expected to be reduced by 3251 short-tonnes per megawatt-hour (MWh) of electricity produced by wind turbines [28]. According to Kumar et al. (2016), the use of wind power saved 96 million metric tons of CO_2 emissions in the U.S. in 2013

[2]. Similarly, when compared to the combustion of coal (which is the second important source of the U.S. electricity [34]), per MWh energy of wind-powered electricity produced, NO_X emissions are expected to reduce by 20 short-tonnes and SO_2 emissions are expected to reduce by 421 short-tonnes [28].

Conventional and nuclear power plants use large amounts of water for cooling, cleaning and fuel processing purposes [28]. This is a potential issue because, globally, water supplies are under severe pressure [35]. For each MWh of electricity produced, natural gas powered plants consume 803 liters, coal powered plants consume 2090 liters and nuclear energy powered plants consume 2590 liters of water [36]. In comparison, the total water use for the same amount of electricity produced by wind powered plants is only 4 liters [28]. Thus, per MWh energy of wind-powered electricity, the water use is expected to decrease by 799, 2086, and 2586 liters compared to the natural gas powered plants, coal powered plants and nuclear plants, respectively.

Wind power technologies allows us to substitute conventional energy for a clean source of energy. Including the air emissions and water use, the current study investigates the importance of air quality and water resource management measures in wind energy deployment. Following the statement of the US–DOE in the Wind Vision initiative [32], we expect that as CO_2 emissions, NO_X emissions (as representative of air quality measures[i]) and water use decrease, the installed capacity of wind energy increases.

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[i] SO_2 and mercury are the two other air quality measures that could be used in the current study. Mercury was not used as a result of limited data availability (data was available for only three years, 2000, 2004, 2005). For SO_2, data availability was the same as NO_X, but compared to SO_2, the correlation with the installed wind power capacity was stronger for

Unlike economic and environmental factors, social factors have often been considered in the wind energy deployment literature. Mainly as a result of the visual impact of wind farms on the landscape, social acceptance was considered an important barrier to achieve states' energy portfolios targets for wind power and frequently studied by the scholars [29]. Arguing that wind turbines are "a matter of public, political, and regulatory acceptance," Carlman (1982) introduced the social acceptance problem of wind power to the literature [37]. Wolsink (1987), Bosley and Bosley (1988), and Thayer (1988) addressed public attitudes towards wind power deployment in the U.S. and in the Netherlands, and defined landscape issues as barriers [38]–[40].

Saidur et al. (2011) related the social acceptance problem of wind turbine technologies to the damage to wildlife (e.g., birds, bats, and raptors), noise, and visual impact, and suggested that environmental threats to the community created by the introduction of wind turbines should be determined by investors and negotiated with locals prior to the siting decisions being made [28]. Similarly, Wüstenhagen et al. (2007) stated that the social resistance needs to be properly addressed, and investment and siting decisions need to be made by a multitude of stakeholders [29].

Trust emerged as another important factor in the literature on wind power implementation. Wolsink (2007) qualitatively analyzed the public attitude towards wind power deployment in Europe and emphasized the importance of policy actors in the decision making processes for wind energy deployment [41]. Likewise, within a

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NO_X emissions. The current study uses the emission that had a higher correlation among the states framework of multiple case studies based in the Netherlands, England and Germany, Breukers and Wolsink (2007) stated that the stability and reliability on the continuum of support systems was as important as the design of the support systems [42].

Combining the importance of social acceptance and support systems, Jobert et al. (2007) focused on five case studies in France and Germany and investigated the local acceptance of wind power. Their findings confirmed the significance of both local (territorial) factors (such as social acceptance) and institutional conditions (such as economic incentives and regulations) on the development of wind energy at the local-level [43].

Institutional support systems (policies and programs) were also the focus of the literature on wind power development in the U.S. In addition to the market conditions, Bird et al. (2005) also explored the significance of policy tools driving wind power development in 12 states and suggested that renewable portfolio standards (RPS) were among numerous drivers (factors that were positively related to wind energy deployment) of the development of wind power in the U.S. [18]. Menz and Vachon (2006) empirically investigated the effectiveness of different policy regimes (RPS, fuel generation disclosure rules, mandatory green power options, and public benefits funds) for promoting wind power in 37 states from 1998 to 2003, and revealed that only RPS and mandatory green power options had a positive influence on wind power development [44]. Maguire (2016) focused on 37 states and empirically investigated the relationship between state policy measures and commercial scale wind energy capacity. Unlike previous studies, neither RPS nor Green

Power Purchasing programs were found to significantly impact the increase in wind energy capacity for the period between 1994 and 2012 [45].

Based on the literature review, most of the previous work has centered on the social dimension, and therefore there is a need to further explore economic and environmental factors that could impact wind energy generation capacity deployment in the U.S. that has experienced the fastest growth in the global wind power industry. The main contribution of the current study is the inclusion of new economic and environmental factors such as the contribution of the agricultural sector to the national economy, NO_X emissions and water use, to understand the deployment of U.S. wind energy using data from 39 states over a 16-year period.

In sum, the current study expects that economic factors (gross state product; the value of agricultural sector and the percentage rate of unemployment) have a positive relationship, and environmental factors (CO_2 emissions, NO_X emission and water use) have a negative relationship with the installed wind energy generation capacity from 2000 to 2015 in the U.S.

2. Methods

2.1. Study Period and Data Description

The current study covers the period from 2000 to 2015. The years prior to 2000 are not included because there were fewer than 10 states with installed wind capacity in the United States and country's wind energy production level was less than 5000 gigawatt hours (GWh) annually [46]. The end point of 2015 was selected because of data availability.

As a proxy for wind energy deployment, the current study uses the installed capacity for wind power data for all U.S. states with existing energy generation capacity. Based on the most recent information available from the US-EIA [46], Table 1 presents a list of the states with and without installed capacities in 2015.

Table 1: States with and without installed wind energy generation capacities in 2015 [4]

States with Installed Wind Energy Generation Capacities in 2015*		
Alaska (AK)	Massachusetts (MA)	Oklahoma (OK)
Arizona (AZ)	Michigan (MI)	Oregon (OR)
California (CA)	Minnesota (MN)	Pennsylvania (PA)
Colorado (CO)	Missouri (MO)	Rhode Island (RI)
Delaware (DE)	Montana (MT)	South Dakota (SD)
Hawaii (HI)	Nebraska (NE)	Tennessee (TN)
Idaho (ID)	Nevada (NV)	Texas (TX)
Illinois (IL)	New Hampshire (NH)	Utah (UT)
Indiana (IN)	New Jersey (NJ)	Vermont (VT)
Iowa (IA)	New Mexico (NM)	Washington (WA)
Kansas (KS)	New York (NY)	West Virginia (WV)
Maine (ME)	North Dakota (ND)	Wisconsin (WI)
Maryland (MD)	Ohio (OH)	Wyoming (WY)
States without Wind Energy Generation Capacities in 2015*		
Alabama (AL)	Georgia (GA)	North Carolina (NC)
Arkansas (AR)	Kentucky (KY)	South Carolina (SC)
Connecticut (CT)	Louisiana (LA)	Virginia (VA)
Florida (FL)	Mississippi (MS)	
As of 12/31/2015		

Detailed information on the variables including unit (as used in the current study), availability (for the time period between 2000 and 2015) and the source is provided in Table 2. The installed capacity for wind power data was calculated using the generator-level nameplate capacities provided by the US-EIA [4], using only the operating and standby generators. Due to the limited availability of the state level water consumption data for the study period, water use data was calculated using the natural gas, coal and nuclear energy sourced electricity data from the US-EIA and the water consumption factors that are provided by the National Energy Technology Laboratory of the US–DOE. With the exception of unemployment data, which were shown as percentages, all data were normalized using population statistics provided by the U.S. Census Bureau [47]–[49]; per capita values are used in our analysis.

Table 2. Variable description

Variable	Unit	Definition	Availability	Source
windcap	watts (W)	Installed capacity for wind power	2000 - 2015	"Electricity: Form EIA-860 detailed data (generator-level specific information)" by U.S. Energy Information Administration [4]
gsp	hundred dollars ($100)	Gross state product	2000 - 2015	"Annual GDP by State" by U.S. Department of Commerce - Bureau of Economic Analysis [50]
agsec	ten dollars ($10)	Net value-added to U.S. economy by agricultural sector	2000 - 2011	"Correlates of State Policy" by Michigan State University - Institute for Public Policy and Social Research [51]
unempl	per mille (‰)	Unemployment	2000 - 2015	"States: Employment status of the civilian noninstitutional population, 1976 to 2016

				annual average” by U.S. Department of Labor - Bureau of Labor Statistics [52]
co2	hundred kilograms (100kg)	Carbon dioxide emissions	2000 - 2014	“State Carbon Dioxide Emissions” by U.S. Energy Information Administration [53]
nox	kilograms (kg)	Nitrogen oxide emissions	2000, 2004, 2005, 2007, 2009, 2010, 2012	“Emissions & Generation Resource Integrated Database (eGRID)” by U.S. Environmental Protection Agency [54]
wateruse	thousand tonnes (1000t)	Water consumption	2000-2015	“Power Systems Life Cycle Analysis Tool (Power LCAT)” by U.S. Department of Energy - National Energy Technology Laboratory (water consumption factors) [36], “Consumption of Fuels to Generate Electricity” by U.S. Energy Information Administration (electricity generation by energy source) [55]

Missing observations were imputed based on the time trend of all available data regardless of study period (2000 to 2015[i]) using linear regression analysis. For example, 2015 CO_2 emissions were missing for all states and data were available from 1990 to 2014. We therefore imputed the 2015 CO_2 emissions (response) using a linear regression with

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[i] For the missing data points of NO_X emissions, both coal consumption- and time trend-based imputations were calculated. Compared to coal consumption-based imputations, the correlation with the installed wind power capacity was stronger for time trend-based imputations. Therefore, the current study uses time trend-based imputations for the missing data points of NO_X emissions.

the data from 1990 to 2014 (e.g., time as the predictor). The only exception was when the imputed values of NO_X emissions were negative. Considering that these emission levels cannot be negative, the last known positive value was used whenever the imputed value from the linear regression analysis of NO_X on time was negative.

2.2. Empirical Model

The objective of the current study is to analyze the relationship of economic and environmental factors with wind energy deployment in the U.S. states over time.

The empirical model has the following form:

$$windcap_{it} = b_1 gsp_{it} + b_2 agsec_{it} + b_3 unempl_{it}$$
$$+ b_4 co2_{it} + b_5 nox_{it} + b_6 watuse_{it} + a_i + u_{it},$$

where *i = 1, …, N* represents each state in the panel (N=39) and *t = 1, …, T* refers to the time period (T=16). *windcap* is installed capacity for wind power per capita; *gsp* is gross state product per capita; *agsec* is the net per capita value-added by the agricultural sector to the U.S. economy regardless of the ownership; *unempl* is the percentage rate of unemployment; *co2* is the CO_2 emissions per capita; *nox* is the NO_X emissions per capita; and the *watuse* is the water consumption per capita. a_i and u_{it} denotes state-specific fixed effects and idiosyncratic errors, respectively. In addition to the linearity in predictors, the assumptions of the panel data analysis, including no perfect collinearity, strict exogeneity, homoskedasticity, no serial correlation and normality, were verified prior to the analysis (see Appendix A for the full list of assumptions as well as their definitions, test methods, Stata codes and results) [55]. Water use did not satisfy the strict exogeneity assumption (that is to say, the variable was found to be correlated with the error term in the original model and called endogenous). Therefore, we considered the model both with and without water use to examine the relationship with installed wind power capacity per capita but report on the model without water use to insure unbiased coefficient estimates. The assumptions were retested for the model excluding water use. Two assumptions that the model failed to satisfy, serial correlation and homoskedasticity, were corrected using Hoechle's (2007) method [56].

The focus of the current analysis is 39 U.S. states with non-uniform installed wind energy capacities. In the current study, panel data analysis allows for flexibility in modelling differences in behavior across individual states [57]. Statistically, data for the individual states also help us to minimize multicollinearity problems, which can be related to the use of macro level data [58]. In addition to the typical assumptions of panel data analysis, the current study assumes that the unobserved characteristics of the states (such as geographic features or historical factors) are related to the existing parameters of the regression. Therefore, a fixed-effects panel data model, which considers correlation exists between unobserved variables and the existing regressors [59], was preferred and used in our analysis. A significance level of 0.05 was used for all tests of significance.

3. Results and discussion

The descriptive statistics, including means, standard deviations, minimums and maximum, for the variables and for 39 states which are used for empirical analysis of the wind energy deployment in the U.S. are presented in Appendix B and C, respectively. The statistics for the installed wind energy capacity illustrate a continuous increase in the mean per capita values from 2000 to 2015. Over the course of 16 years, average per capita values for the installed capacity of wind power increased more than 40 times. Nevertheless, the increase in the installed wind energy generation capacities did not follow the same path for all states. Table 3 presents the state-level per capita installed wind energy generation capacities for 39 states from 2000 to 2015 (see Appendix D for the total installed wind energy generation capacities of the states). An important level of disparity exists in states' installed wind energy generation capacities. By 2015, there are still 15 states with per capita installed wind energy generation capacities lower than 100 W, whereas per capita capacity (/capacities) in Kansas and Oklahoma exceed 1000 W, in New York and Wyoming exceed 2000W and in Iowa exceeds 3000W thresholds. Similarly, total levels of installed wind capacity is still low in many states: for 27 states, the total installed capacity for wind energy is still less than 2250 megawatts (MW) by 2015. For the entire study period, Texas is the leader and has an installed wind energy generation capacity of 17662 MW in 2015. California, Iowa and Oklahoma follows Texas with wind energy generation capacities that exceed 5000 MW; and Colorado, Illinois, Kansas, Minnesota, North Dakota, Oregon and Washington have wind energy generation capacities over 2250 MW.

Table 3: Installed wind energy generation capacities of U.S. states between 2000 and 2015 (per capita) [4]

windcap **(W/cap)**	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Alaska	0	0	0	1	1	14	4	4	4	11	10	10	45	81	99	82
Arizona	0	0	0	0	0	0	0	0	0	22	44	47	80	80	80	90
California	47	46	50	55	57	57	63	64	65	72	75	99	145	147	151	147
Colorado	4	12	13	49	50	50	61	222	218	249	257	352	443	442	485	544
Delaware	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3
Hawaii	9	9	9	9	9	9	33	48	48	47	45	66	126	125	124	123
Idaho	0	0	0	0	0	1	6	6	9	11	27	48	75	75	75	75
Illinois	0	0	0	8	8	17	17	116	150	247	300	420	542	540	538	578
Indiana	0	0	0	0	0	0	0	0	43	342	439	437	501	498	560	557
Iowa	246	241	311	339	447	574	627	777	1734	2216	2332	2715	3198	3195	3467	3820
Kansas	0	41	41	42	41	96	132	131	289	357	375	443	942	1026	1024	1229
Maine	0	0	0	0	0	0	0	7	7	26	40	49	65	64	64	90
Maryland	0	0	0	0	0	0	0	0	0	0	12	21	20	20	27	32
Massachusetts	0	0	0	0	0	0	0	1	1	3	8	23	49	56	63	63
Michigan	0	0	0	0	0	0	0	0	12	14	17	38	89	117	154	154
Minnesota	62	61	67	93	102	134	161	219	282	310	378	482	529	525	559	592
Missouri	0	0	0	0	0	0	0	19	55	104	154	154	154	153	153	153
Montana	0	0	0	0	0	144	152	171	278	381	389	385	639	634	647	642
Nebraska	2	3	2	10	10	56	55	54	54	116	161	252	345	401	611	665
Nevada	0	0	0	0	0	0	0	0	0	0	0	0	15	15	15	15
New Hampshire	0	0	0	0	0	0	0	0	3	3	3	3	19	19	19	19
New Jersey	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4
New Mexico	0	0	0	11	14	21	26	26	26	31	36	38	40	40	41	54
New York	28	28	75	75	75	286	570	650	1075	1915	1888	2041	2337	2396	2367	2314
North Dakota	0	0	0	29	27	39	65	147	317	495	573	570	655	647	636	785
Ohio	0	0	0	0	1	1	1	1	1	1	1	14	40	41	37	37
Oklahoma	0	0	0	50	50	134	165	190	193	304	394	478	821	813	975	1283
Oregon	46	46	52	63	63	83	109	238	283	437	524	573	811	805	796	785
Pennsylvania	3	3	3	11	11	11	12	23	29	59	59	62	105	105	105	104
Rhode Island	0	0	0	0	0	0	0	0	0	0	1	1	1	1	6	6
South Dakota	0	3	3	56	56	56	55	54	242	396	770	946	947	936	774	977
Tennessee	0	0	0	0	5	5	5	5	5	5	5	5	4	4	4	4
Texas	0	43	50	58	57	81	117	182	300	372	389	404	467	466	520	644
Utah	0	0	0	0	0	0	0	0	7	82	80	115	114	112	110	108
Vermont	1	1	1	1	1	1	1	1	1	1	1	6	15	15	15	14
Washington	0	30	38	40	39	63	129	180	208	301	341	360	408	403	436	430
West Virginia	0	0	12	12	12	12	12	12	59	58	76	92	102	102	101	101
Wisconsin	13	30	29	29	29	29	29	29	198	243	253	340	342	342	345	346
Wyoming	12	285	282	566	560	559	550	537	1246	1972	2506	2522	2485	2459	2455	2443

windcap = 0	1000 < *windcap* ≤ 1500	2500 < *windcap* ≤ 3000
0 < *windcap* ≤ 500	1500 < *windcap* ≤ 2000	3000 < *windcap* ≤ 3500
500 < *windcap* ≤ 1000	2000 < *windcap* ≤ 2500	3500 < *windcap* ≤ 4000

The mean per capita values for gross state product and value-added by agricultural sector to the U.S. economy also present increasing trends for all 39 U.S. states for the years between 2000 and 2015. There is no increasing or decreasing trend in the mean unemployment rates between 2000 and 2015, but overall, there is a slight increase in 2015 compared to the year 2000. The mean values as well as the standard deviation of state-level emissions presents a decreasing trend for both CO_2 and NO_X for the entire study period. Finally, the state-level water use does not present any increasing or decreasing trend, but the per capita water use on average is considerably lower in the final year of the study period, 2015, compared to the start year of the study period, 2000.

The results of the fixed-effects panel data analysis are presented in Table 4. The results suggest statistically significant relationships for all economic and environmental factors with installed wind energy capacities in the states from 2000 to 2015. An increase in economic factors (the gross state product per capita; the net per capita value-added by the agricultural sector to the U.S. economy, and the percentage rate of unemployment) is related to an increase in installed wind energy capacities, whereas, an increase in environmental factors (per capita CO_2 and NO_X emission levels) is related to a decrease in installed wind capacities.

Table 4. Fixed-effects panel data regression analysis coefficients, standard errors, and p-values

Independent variables	Coefficient Estimates	Standard Errors	P-values
gsp ($100/capita)	1.868	0.548	0.002
agsec ($10/capita)	2.636	0.452	0.000
unempl (‰)	1.640	0.605	0.010
co2 (100kg/capita)	-1.394	0.504	0.009
nox (kg/capita)	-5.624	1.202	0.000
Intercept	-561.7	290.7	0.054
Dependent variable: windcap (W/capita)			

The positive and statistically significant relationship between gross state product and installed wind energy generation capacity suggests that higher state income is associated with a greater installed wind energy capacity for 39 U.S. states from 2000 to 2015. Higher income may be related to a wealthier economy as well as greater support for the cost of state's financial incentives [20]. Correspondingly, switching from one technology to another, a stronger economy as well as a greater level of economic support may incentivize shareholders in making investment decisions for wind energy.

The positive relationship between the unemployment levels and the installed wind energy capacities in the current study may suggest that higher unemployment is associated with higher wind energy capacity installments. Being an emerging industry, wind energy is expected to create new jobs in the states for both manufacturing and maintenance of wind turbines. Currently, wind energy provides only 5.6% of the U.S. electricity and there are over 53000 wind turbines and 500 wind turbine manufacturing facilities spread across the U.S [60]. The goal is to generate 35% of U.S. electricity by 2050 [61]. According to the US–DOE, once the country achieves this goal, the sector will be able to support 600000 direct and indirect jobs in the entire U.S. [61].

The results also present a complementary relationship between the contribution of the agricultural sector to the national economy and states' wind power capacity. The agricultural sector provides the land where wind energy turbines are built and farmers might still use most of their farmland for activities such as farming, ranching and forestry [32]. Our results suggest that the greater investment levels in agricultural activities may be associated to the greater income levels from the wind energy installations.

The relationship between air emission levels (CO_2 and NO_X) and wind energy deployment were found to be negative in the current analysis. Along with the descriptive statistics presented in Appendix B, the results suggest that the decreased levels of CO_2 and NO_X emissions are associated with an increase in the installed wind power capacity in the U.S. Regarding the fact that both CO_2 and NO_X emissions are considered byproducts of conventional energy sources (e.g., natural gas and coal), the statistically significant relationship between CO_2 and NO_X emissions and wind energy deployment may also signify the substitution of the electricity produced by conventional energy sources by the wind power sourced electricity from 2000 to 2015 in 39 U.S. states.

The current study calculated state's water consumption levels using the annual plant-level electricity production data of coal, natural gas and nuclear power industries which uses large amounts of water for cooling, cleaning and fuel processing purposes. Increase use of wind-powered electricity can help reducing the pressure on water supplies. In the current study, water use was found endogenous (that is to say, correlated with the error term in the original model). Endogeneity may occur from three important causes: (i) a time-varying variable which is related to both endogenous variable (water use) and response variable (wind energy deployment) might have been omitted in the model [54], (ii) a measurement error might have occurred in data of the endogenous variable [54], or (iii) the relationship of endogenous variable (water use) and response variable (wind energy deployment) might have been bidirectional (in other words, simultaneous), or the direction of causality between the variables might have been anticipated reversed in the original model (that is, wind energy deployment might be related to the water use instead of water use is related to the wind energy deployment) [58].

4. Conclusion

The current study investigated the significance of a number of economic and environmental factors on the wind energy deployment in the U.S. Using data from 39 states from 2000 to 2015, our analysis included factors that had not been previously studied within the wind energy and renewable energy deployment literature, such as the level of income in the agricultural sector, NO_X emissions and water use.

Our analysis could be expanded and improved in several ways. First, the current study excludes water use to ensure unbiased coefficient estimates for the wind energy deployment in the U.S. and leaves the investigation of the main reason behind the endogeneity of water use for further research. The inclusion of water consumption levels may further contribute the understanding of the relationship between natural resource management, in particular water resource management, and the increased use of renewable sources of energy.

Our second suggestion would be to expand the data set through the use of other sets of factors, such as social and political ones. The literature on countries' renewable energy deployment defines seven main categories of factors: economic, environmental, political, regulatory, social, technical potential, and technological. Even though there is an important number of studies focusing on the social acceptance of wind power at the country level, there is no study that incorporates other social factors such as state demographics along with the economic and environmental variables for U.S. states. Similarly, we suggest that future research focused on other countries or country groups may shed more light on the role of economic and environmental factors in the increase of wind energy generation capacities worldwide.

The interaction between variables may also be taken into account in future analysis. Interaction is assumed to exist when the simultaneous influence of two explanatory variables on the dependent variable is not additive. Including interaction terms (e.g., the interaction between the economic and environmental) in future studies can allow for researchers to distinguish between the separated and simultaneous impact of the factors impacting wind energy deployment of the country. Particularly, the behavioral difference of factors on the wind energy deployment under democratic and republican state control represents an important area to investigate on state level wind energy deployment in the U.S.

Finally, considering the state-level heterogeneity which was represented by the descriptive statistics of the current analysis, future scholars may use a hierarchical model that distinguishes the regions, income groups, deployment levels, or the start dates of the wind power capacity installations to analyze the influence of factors impacting renewable energy deployment across the country. The current study takes only time-varying variables into consideration. Taking into account state-fixed effects such as geographic factors and historical features, future scholars may use a mixed effects regression analysis for a more comprehensive explanation for the wind energy deployment of individual states.

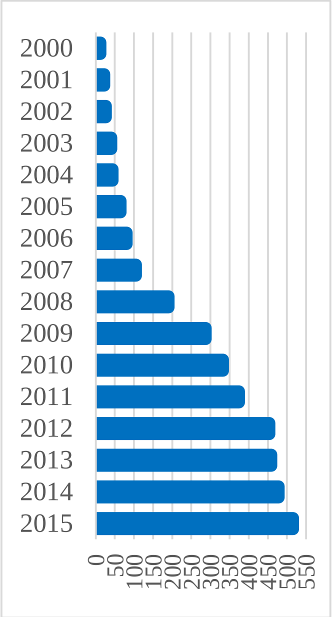
Appendix A. Assumptions of the fixed effects panel data analysis

Assumption[55]	**Definition**	**Test method**	**Stata code**	**Results**
No perfect collinearity	All explanatory variables change over time and there is no perfect linear relationship among them.	Variance inflation factors are used to test for the bias estimates [62].	The Stata command to test the model for multicollinearity is *vif*.	No perfect linear relationships among the explanatory variables was found: The computed variance inflation factor values varied between 1.06 and 5.66 for the model including water use and between 1.44 and 5.66 for the model excluding water use. Further investigation would be needed if the computed variance inflation factor values were greater than 10 (or tolerances – 1/vif – were lower than 0.10) [62]
Strict exogeneity	Explanatory variables of the model are uncorrelated with the idiosyncratic errors, u_{it}, for each time period.	Davidson MacKinnon test is used to examine the exogeneity of explanatory variables, one at a time. The test procedure compares the results of the original model with an upgraded model including additional (instrumental) variables that are in potential relationship with	The Stata command to create the additional instrumental variable is *xtivreg* and the command to compare the results of the	The null hypothesis of exogeneity was failed to be rejected for all explanatory variables except water use. The endogenous variable was taken out of the model to satisfy strict exogeneity of the explanatory variables.

		the existing explanatory variables of the original model [63].	two models is *dmexogxt*.	
Homoskedasticity	The variance of the idiosyncratic error, u_{it}, remains the same identical for all values of the dependent variable: $Var\ (u_{it} \vert X_i a_i) = Var\ (u_{it}) = \sigma_u^2, for\ all\ t = 1, \ldots, T$	White test is used to detect heteroscadasticity. White test is a generalized case of Breusch Pagan test to detect both linear and nonlinear forms of heteroscadasticity [64].	The Stata command for the White test is *imtest, white*.	The null hypothesis of homoskedasticity was rejected for both models (for the model with water use and for the model without water use).
No serial correlation	Conditional on all explanatory variables and unobserved heterogeneities, a_i, the idiosyncratic errors, u_{it}, are uncorrelated over time: $Cov\ (u_{it}, u_{is} \vert X_i, a_i) = 0$	Woolridge's test for serial correlation is used to identify the correlation among the idiosyncratic errors, u_{it}, over time [65]	The Stata command to test serial correlation is *xtserial*.	The null hypothesis of no serial correlation among the idiosyncratic errors, u_{it}, was failed to be rejected for both models (for the model with water use and for the model without water use).
Normality	The idiosyncratic error, u_{it}, is independent and identically distributed as N (0, σ_u^2) for each t.	An extension of Jarque-Bera normality test is proposed by Alejo *et al*. (2015) to explore skewness and excess kurtosis of the idiosyncratic error, u_{it} [66].	The Stata command to test the idiosyncratic error, u_{it}, for normality is *xtsktest*.	No statistically significant skewness and excess kurtosis were detected for the idiosyncratic error, u_{it}, in both models (in the model with water use and in the model without water use).. The normality assumption was verified.

Model specification: $y_{it} = \beta_1 x_{it1} + \cdots + \beta_k x_{itk} + a_i + u_{it}, i = 1, \ldots, 39\ and\ t = 1, \ldots, 16$, where β_j are the parameters to estimate, a_i is the unobserved heterogeneity, and u_{it} is the idiosyncratic error.

Appendix B. Summary statistics of variables [i]

Year	Mean	Std. Dev.	Min.	Max.	*windcap (W/capita)*
2000	12.13	41.07	0.00	245.91	
2001	22.65	59.32	0.00	285.05	
2002	26.65	67.00	0.00	310.51	
2003	41.22	103.54	0.00	566.09	
2004	44.23	112.07	0.00	559.80	
2005	64.89	131.68	0.00	574.41	
2006	81.00	155.74	0.00	627.23	
2007	105.57	180.10	0.00	777.29	
2008	190.87	365.36	0.00	1734.25	
2009	287.31	534.99	0.00	2215.85	
2010	332.53	596.45	0.00	2506.41	
2011	374.87	645.04	0.00	2715.41	
2012	454.39	716.92	1.42	3198.11	
2013	459.21	718.89	1.42	3194.83	
2014	478.09	744.21	3.03	3466.84	
2015	515.80	793.13	2.98	3820.12	

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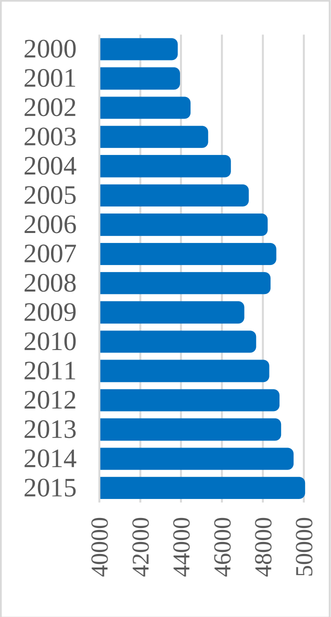
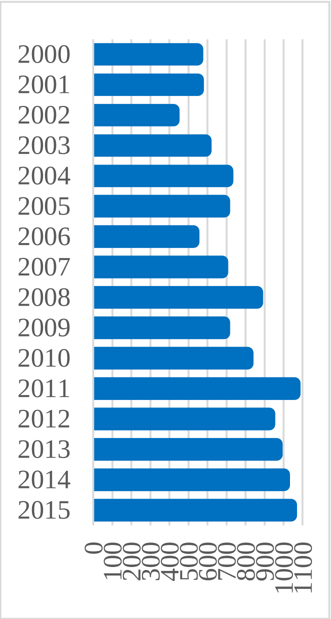
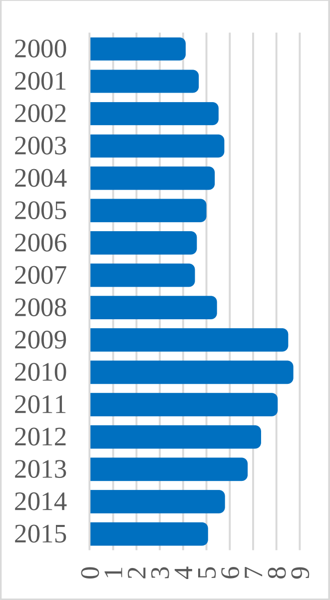
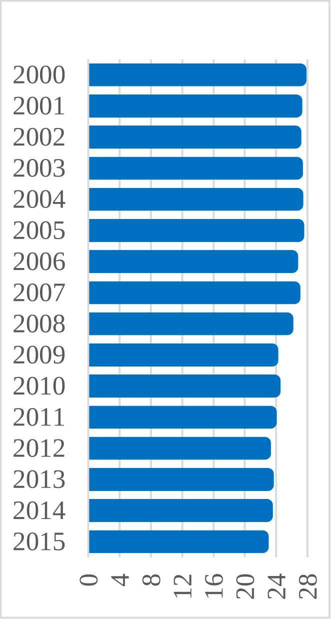
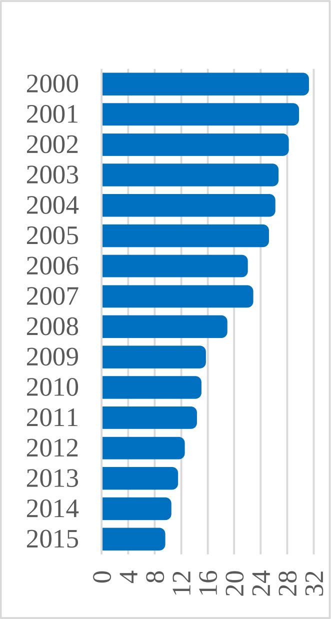
[i] In the tables, installed capacity for wind power per capita, gross state product per capita, the net per capita value-added by the agricultural sector to the U.S. economy, the percentage rate of unemployment, CO_2 emissions per capita, the NO_X emissions per capita, and the water consumption per capita are represented by *windcap, gsp, agsec, unempl*, *co2*, *nox*, and *watuse* respectively.

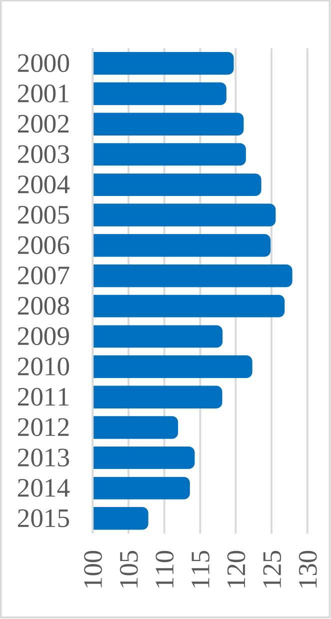
Year	Mean	Std. Dev.	Min.	Max.	*gsp ($/capita)*
2000	43544.26	7748.49	31899.00	68992.00	
2001	43659.54	8062.73	32263.00	71155.00	
2002	44178.59	7633.29	32506.00	67853.00	
2003	45028.64	7457.04	32396.00	67956.00	
2004	46147.44	7583.45	32862.00	69500.00	
2005	47023.05	7609.13	33628.00	67525.00	
2006	47948.72	7954.21	34009.00	67857.00	
2007	48375.41	8117.92	33892.00	67228.00	
2008	48093.69	8094.14	34679.00	69182.00	
2009	46807.05	8643.29	34564.00	72204.00	
2010	47386.77	8291.53	34621.00	69565.00	
2011	48021.08	8380.00	34270.00	70573.00	
2012	48520.13	8933.30	34090.00	73464.00	
2013	48601.03	8505.86	34795.00	69596.00	
2014	49219.51	8621.23	34949.00	70684.00	
2015	49776.87	8459.55	35455.00	67278.00	

Year	Mean	Std. Dev.	Min.	Max.	*agsec ($/capita)*
2000	547.69	731.90	25.78	3115.01	
2001	550.58	672.66	27.96	2679.85	
2002	422.23	489.53	29.09	2022.54	
2003	590.41	810.91	29.53	3514.55	
2004	705.20	882.27	34.96	3736.22	
2005	688.69	859.01	32.51	3490.48	
2006	527.14	602.97	24.56	2280.04	
2007	678.18	909.74	23.43	3603.86	
2008	860.99	1279.96	17.09	5171.19	
2009	687.91	1075.39	21.57	4497.81	
2010	811.41	1215.95	24.79	5417.24	
2011	1057.72	1600.34	23.91	6808.50	
2012	925.70	1387.66	14.81	5522.79	
2013	963.91	1460.73	12.37	5813.61	
2014	1002.12	1533.88	9.94	6104.42	
2015	1040.33	1607.10	7.50	6395.24	

Year	Mean	Std. Dev.	Min.	Max.	*unempl (%)*
2000	3.86	0.90	2.50	6.40	
2001	4.42	0.88	2.90	6.40	
2002	5.27	1.07	3.20	7.50	
2003	5.51	1.11	3.50	8.10	
2004	5.11	1.03	3.40	7.50	
2005	4.76	0.91	2.90	6.90	
2006	4.33	0.93	2.60	7.00	
2007	4.25	0.98	2.60	7.00	
2008	5.19	1.26	3.10	8.00	
2009	8.25	2.03	4.10	13.70	
2010	8.47	2.13	3.80	13.50	
2011	7.81	1.98	3.50	13.00	
2012	7.09	1.80	3.10	11.20	
2013	6.52	1.64	2.90	9.60	
2014	5.54	1.32	2.70	7.90	
2015	4.81	1.10	2.70	6.70	

Year	Mean	Std. Dev.	Min.	Max.	*co2 (t/capita)*
2000	27.12	22.65	11.16	127.99	
2001	26.58	22.53	10.78	128.17	
2002	26.46	22.34	10.40	124.20	
2003	26.66	22.50	10.56	127.12	
2004	26.71	22.16	10.14	125.51	
2005	26.82	22.26	10.49	123.11	
2006	26.08	22.02	9.88	122.64	
2007	26.35	22.20	10.43	124.33	
2008	25.44	21.75	9.45	122.52	
2009	23.52	20.11	9.01	113.96	
2010	23.82	20.56	8.99	115.67	
2011	23.34	20.32	8.45	113.08	
2012	22.57	20.60	8.24	115.12	
2013	22.97	20.69	8.27	117.73	
2014	22.82	20.15	8.61	112.40	
2015	22.28	20.01	7.95	111.73	

Year	**Mean**	**Std. Dev.**	**Min.**	**Max.**	***nox (kg/capita)***
2000	30.40	38.70	0.80	186.19	
2001	28.87	37.92	0.52	186.01	
2002	27.33	36.08	0.52	178.64	
2003	25.79	34.27	0.51	171.28	
2004	25.32	35.43	0.57	185.78	
2005	24.36	34.03	0.53	177.75	
2006	21.15	29.02	0.50	149.18	
2007	22.00	30.39	0.53	153.52	
2008	18.09	25.74	0.49	134.45	
2009	14.84	23.87	0.47	123.88	
2010	14.18	21.36	0.47	112.55	
2011	13.49	21.35	0.48	112.35	
2012	11.64	17.23	0.31	85.98	
2013	10.62	18.88	0.36	97.62	
2014	9.62	17.62	0.25	90.25	
2015	8.70	16.36	0.06	82.89	

Year	**Mean**	**Std. Dev.**	**Min.**	**Max.**	***watuse (1000t/capita)***
2000	118.88	126.85	1.01	543.88	
2001	117.86	124.81	1.28	533.86	
2002	120.26	128.51	0.45	546.45	
2003	120.57	127.80	1.29	542.29	
2004	122.72	131.71	1.58	567.47	
2005	124.76	133.33	1.48	567.81	
2006	124.03	133.98	1.21	571.72	
2007	127.08	135.93	1.51	574.11	
2008	126.01	134.30	1.55	568.17	
2009	117.32	127.32	1.49	550.03	
2010	121.48	131.99	1.54	570.99	
2011	117.26	132.25	1.07	593.69	
2012	111.10	124.76	1.69	559.93	
2013	113.44	127.96	2.92	575.14	
2014	112.77	126.93	2.21	575.83	
2015	106.97	119.56	2.56	546.88	

Appendix C. Summary statistics of states

Alaska	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	22.96	33.93	0.00	98.68
gsp ($/capita)	65300.63	5273.55	57184.00	73464.00
agsec ($/capita)	25.79	12.32	7.50	47.50
unempl (%)	7.03	0.54	6.30	7.90
co2 (tonne/capita)	60.24	9.23	46.61	71.97
nox (kg/capita)	17.47	4.10	10.77	23.89
wateruse (1000tonnes/capita)	4.24	0.23	3.81	4.55

Arizona	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	27.68	36.24	0.00	89.76
gsp ($/capita)	40024.75	2180.80	37936.00	44168.00
agsec ($/capita)	233.90	45.78	130.54	325.11
unempl (%)	6.46	2.13	3.90	10.40
co2 (tonne/capita)	15.57	1.22	13.84	17.09
nox (kg/capita)	12.25	3.75	7.28	20.31
wateruse (1000tonnes/capita)	183.69	10.80	168.46	198.56

California	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	83.67	39.96	46.31	150.79
gsp ($/capita)	52283.44	2865.36	47216.00	56851.00
agsec ($/capita)	482.83	92.00	348.06	627.67
unempl (%)	7.57	2.52	4.90	12.20
co2 (tonne/capita)	10.32	0.81	9.14	11.29
nox (kg/capita)	0.78	0.33	0.47	1.73
wateruse (1000tonnes/capita)	167.37	15.59	141.81	190.41

Colorado	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	215.63	189.60	3.84	543.90
gsp ($/capita)	50864.63	1036.52	49258.00	52558.00
agsec ($/capita)	409.06	57.82	307.40	489.94
unempl (%)	5.59	1.79	2.80	8.70
co2 (tonne/capita)	19.22	1.37	17.12	20.95
nox (kg/capita)	13.50	3.15	8.55	17.97
wateruse (1000tonnes/capita)	81.26	3.18	75.27	87.16

Delaware	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	1.17	1.57	0.00	3.30
gsp ($/capita)	65620.50	3141.94	60557.00	71155.00
agsec ($/capita)	345.57	77.86	197.40	523.39
unempl (%)	5.26	1.78	3.40	8.40
co2 (tonne/capita)	17.28	3.14	12.87	21.31
nox (kg/capita)	9.02	6.02	0.61	17.37
wateruse (1000tonnes/capita)	9.15	2.11	6.62	13.28

Hawaii	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	52.57	46.73	8.82	126.17
gsp ($/capita)	48485.19	2388.33	43778.00	51245.00
agsec ($/capita)	296.83	26.35	261.95	339.72
unempl (%)	4.55	1.46	2.60	7.20
co2 (tonne/capita)	15.39	1.90	12.99	18.32
nox (kg/capita)	15.90	3.81	10.90	23.06
wateruse (1000tonnes/capita)	3.22	0.19	2.79	3.44

Idaho	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	25.55	32.08	0.00	75.29
gsp ($/capita)	35001.19	1128.41	33390.00	37080.00
agsec ($/capita)	1642.50	317.64	1129.73	2193.26
unempl (%)	5.63	1.82	3.10	9.00
co2 (tonne/capita)	10.62	0.73	9.64	12.13
nox (kg/capita)	0.51	0.08	0.41	0.80
wateruse (1000tonnes/capita)	1.59	0.69	0.45	3.22

Illinois	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	217.59	233.35	0.00	578.35
gsp ($/capita)	51039.75	1518.87	48849.00	53669.00
agsec ($/capita)	503.10	191.15	219.08	773.91
unempl (%)	7.00	2.04	4.30	10.40
co2 (tonne/capita)	18.29	0.63	16.91	19.33
nox (kg/capita)	9.11	6.16	1.08	19.34
wateruse (1000tonnes/capita)	434.14	14.48	404.89	453.10

Indiana	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	211.04	246.61	0.00	559.74
gsp ($/capita)	42789.25	1441.11	40138.00	45118.00
agsec ($/capita)	585.50	185.89	265.37	851.18
unempl (%)	6.29	2.19	3.10	10.40
co2 (tonne/capita)	34.91	3.32	30.01	39.21
nox (kg/capita)	27.79	16.58	1.92	56.87
wateruse (1000tonnes/capita)	237.00	26.44	176.56	268.69

Iowa	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	1640.02	1331.69	241.07	3820.12
gsp ($/capita)	45179.56	3345.63	38988.00	49532.00
agsec ($/capita)	2904.49	1100.88	1495.91	4765.61
unempl (%)	4.40	0.98	2.60	6.40
co2 (tonne/capita)	27.11	1.12	26.01	29.57
nox (kg/capita)	19.11	6.29	10.53	28.71
wateruse (1000tonnes/capita)	88.02	6.00	77.81	99.87

Kansas	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	388.14	423.42	0.00	1229.46
gsp ($/capita)	43418.81	2449.19	39745.00	46132.00
agsec ($/capita)	1502.30	535.63	592.07	2326.29
unempl (%)	5.15	1.02	3.60	7.10
co2 (tonne/capita)	26.15	1.90	22.94	28.87
nox (kg/capita)	23.11	8.33	11.89	35.43
wateruse (1000tonnes/capita)	91.92	7.80	74.69	104.33

Maine	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	25.77	31.34	0.00	90.33
gsp ($/capita)	38097.69	776.02	36503.00	39288.00
agsec ($/capita)	222.13	24.33	179.73	262.95
unempl (%)	5.56	1.58	3.40	8.10
co2 (tonne/capita)	15.17	2.52	11.39	18.52
nox (kg/capita)	5.31	1.29	3.41	7.91
wateruse (1000tonnes/capita)	6.42	2.42	2.56	12.11

Maryland	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	8.23	11.64	0.00	31.69
gsp ($/capita)	51611.06	2884.12	45619.00	54626.00
agsec ($/capita)	120.30	14.91	80.99	147.76
unempl (%)	5.18	1.46	3.50	7.70
co2 (tonne/capita)	12.73	1.92	9.87	14.93
nox (kg/capita)	7.98	6.01	0.36	16.90
wateruse (1000tonnes/capita)	89.82	11.32	70.69	101.04

Massachusetts	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	16.85	25.43	0.00	63.48
gsp ($/capita)	59458.13	2884.78	54736.00	64017.00
agsec ($/capita)	38.55	4.98	29.07	49.83
unempl (%)	5.63	1.50	2.70	8.30
co2 (tonne/capita)	11.51	1.52	9.25	13.20
nox (kg/capita)	3.18	1.97	0.38	6.45
wateruse (1000tonnes/capita)	48.16	8.10	34.51	58.41

Michigan	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	37.32	57.15	0.06	154.25
gsp ($/capita)	41112.13	1671.84	36676.00	42919.00
agsec ($/capita)	266.37	116.33	121.43	441.73
unempl (%)	7.84	2.62	3.60	13.70
co2 (tonne/capita)	17.56	1.33	15.55	19.52
nox (kg/capita)	10.77	4.21	4.15	17.59
wateruse (1000tonnes/capita)	219.52	15.34	201.09	243.17

Minnesota	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	284.75	199.30	60.75	592.42
gsp ($/capita)	50614.25	1888.15	47177.00	53562.00
agsec ($/capita)	1122.12	421.66	498.78	1751.76
unempl (%)	4.96	1.31	3.20	7.80
co2 (tonne/capita)	18.42	1.39	16.21	20.10
nox (kg/capita)	12.10	5.36	4.73	19.83
wateruse (1000tonnes/capita)	98.50	8.47	81.95	110.74

Missouri	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	68.79	73.13	0.00	154.36
gsp ($/capita)	42291.94	567.34	41346.00	43145.00
agsec ($/capita)	578.11	163.73	274.58	802.87
unempl (%)	6.18	1.69	3.60	9.60
co2 (tonne/capita)	22.99	1.11	21.18	24.75
nox (kg/capita)	16.54	8.80	2.70	29.37
wateruse (1000tonnes/capita)	178.90	9.93	159.39	191.60

Montana	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	278.75	257.13	0.00	647.49
gsp ($/capita)	36374.44	2458.68	31899.00	39046.00
agsec ($/capita)	1257.25	301.21	716.96	1645.30
unempl (%)	5.08	1.14	3.50	7.30
co2 (tonne/capita)	34.65	2.67	30.34	38.98
nox (kg/capita)	23.75	15.51	1.24	46.20
wateruse (1000tonnes/capita)	34.68	2.79	29.61	38.92

Nebraska	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	174.88	219.29	2.05	665.43
gsp ($/capita)	47626.38	3616.97	41761.00	52773.00
agsec ($/capita)	3240.62	1157.21	1443.61	5301.19
unempl (%)	3.64	0.58	2.80	4.60
co2 (tonne/capita)	26.11	1.53	24.31	28.58
nox (kg/capita)	23.55	4.07	15.33	30.72
wateruse (1000tonnes/capita)	70.36	5.01	61.29	78.58

Nevada	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	3.79	6.78	0.00	15.39
gsp ($/capita)	47921.88	4221.98	43054.00	54797.00
agsec ($/capita)	94.67	12.91	72.48	120.03
unempl (%)	7.31	3.35	4.00	13.50
co2 (tonne/capita)	16.35	3.72	10.73	22.72
nox (kg/capita)	11.34	8.77	0.87	26.58
wateruse (1000tonnes/capita)	38.28	8.83	28.84	53.55

New Hampshire	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	5.48	8.26	0.00	19.27
gsp ($/capita)	47716.13	1694.58	44460.00	50162.00
agsec ($/capita)	55.17	9.06	35.96	73.15
unempl (%)	4.30	1.02	2.70	6.20
co2 (tonne/capita)	13.57	1.97	10.81	16.98
nox (kg/capita)	5.68	3.47	0.06	10.74
wateruse (1000tonnes/capita)	34.47	3.79	28.92	40.71

New Jersey	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	2.38	1.92	0.00	4.33
gsp ($/capita)	55775.81	1315.93	53701.00	57860.00
agsec ($/capita)	63.62	9.25	46.98	76.66
unempl (%)	6.31	2.08	3.70	9.50
co2 (tonne/capita)	13.68	1.13	11.78	15.10
nox (kg/capita)	2.20	1.41	0.23	4.88
wateruse (1000tonnes/capita)	114.75	4.30	104.53	119.63

New Mexico	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	25.16	16.49	0.00	53.80
gsp ($/capita)	40180.56	1219.44	37773.00	41558.00
agsec ($/capita)	614.91	135.63	416.30	848.71
unempl (%)	5.93	1.32	3.80	8.10
co2 (tonne/capita)	28.40	2.70	24.05	31.99
nox (kg/capita)	35.06	6.71	25.19	47.89
wateruse (1000tonnes/capita)	61.32	5.23	49.75	67.81

New York	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	1132.53	1001.17	28.18	2396.21
gsp ($/capita)	59122.31	3223.58	53827.00	63390.00
agsec ($/capita)	94.19	23.02	58.03	127.16
unempl (%)	6.26	1.54	4.50	8.60
co2 (tonne/capita)	9.75	1.21	7.95	11.21
nox (kg/capita)	2.54	1.47	0.43	5.33
wateruse (1000tonnes/capita)	175.80	8.81	162.87	191.34

North Dakota	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	311.61	299.23	0.00	785.40
gsp ($/capita)	49868.94	12509.57	35067.00	70684.00
agsec ($/capita)	4018.34	1312.92	2022.54	5850.40
unempl (%)	3.28	0.41	2.70	4.10
co2 (tonne/capita)	79.13	1.37	76.78	81.10
nox (kg/capita)	98.58	23.71	61.65	130.50
wateruse (1000tonnes/capita)	60.02	1.92	56.67	63.25

Ohio	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	10.83	16.97	0.00	41.06
gsp ($/capita)	44036.63	1512.05	41593.00	47109.00
agsec ($/capita)	267.38	87.67	133.08	430.75
unempl (%)	6.55	1.88	4.00	10.30
co2 (tonne/capita)	21.90	1.66	18.86	23.70
nox (kg/capita)	16.87	11.96	1.23	34.81
wateruse (1000tonnes/capita)	289.93	33.80	217.39	326.47

Oklahoma	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	365.56	399.31	0.00	1282.72
gsp ($/capita)	39064.75	3316.77	34015.00	45042.00
agsec ($/capita)	488.74	101.77	223.31	660.43
unempl (%)	4.78	1.04	3.00	6.80
co2 (tonne/capita)	28.87	1.18	27.00	30.69
nox (kg/capita)	22.52	4.05	16.42	29.69
wateruse (1000tonnes/capita)	92.80	6.58	79.50	103.02

Oregon	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	357.01	314.07	45.50	810.80
gsp ($/capita)	45116.31	4906.84	37161.00	51260.00
agsec ($/capita)	529.64	69.20	412.45	595.11
unempl (%)	7.39	1.89	5.10	11.30
co2 (tonne/capita)	10.78	0.89	9.46	12.10
nox (kg/capita)	2.85	0.70	1.16	4.18
wateruse (1000tonnes/capita)	17.63	2.70	13.79	22.41

Pennsylvania	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	43.99	41.43	2.79	105.24
gsp ($/capita)	45792.13	2456.04	41857.00	50540.00
agsec ($/capita)	165.12	30.55	94.77	203.64
unempl (%)	5.97	1.45	4.10	8.50
co2 (tonne/capita)	20.87	1.49	18.68	22.60
nox (kg/capita)	13.55	4.30	7.39	22.07
wateruse (1000tonnes/capita)	440.47	21.58	391.37	472.25

Rhode Island	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	1.07	1.91	0.00	5.69
gsp ($/capita)	45637.06	1954.10	41395.00	48259.00
agsec ($/capita)	33.41	4.45	25.78	40.52
unempl (%)	7.11	2.64	4.10	11.20
co2 (tonne/capita)	10.42	0.53	9.69	11.64
nox (kg/capita)	1.08	0.67	0.60	2.60
wateruse (1000tonnes/capita)	5.33	0.83	3.84	6.88

South Dakota	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	391.97	415.21	0.00	976.55
gsp ($/capita)	43603.13	3842.11	35601.00	47979.00
agsec ($/capita)	4214.12	1603.84	1540.40	6808.50
unempl (%)	3.63	0.75	2.50	5.00
co2 (tonne/capita)	18.00	0.49	17.11	18.81
nox (kg/capita)	17.28	5.39	8.93	24.94
wateruse (1000tonnes/capita)	6.66	1.07	3.75	7.88

Tennessee	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	3.51	1.91	0.31	4.87
gsp ($/capita)	40698.25	1278.02	38631.00	42647.00
agsec ($/capita)	162.35	29.41	94.20	219.82
unempl (%)	6.49	1.94	3.90	10.50
co2 (tonne/capita)	18.94	2.89	14.62	22.50
nox (kg/capita)	13.86	10.50	1.97	31.56
wateruse (1000tonnes/capita)	175.16	23.19	136.06	200.81

Texas	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	259.40	208.21	0.00	643.88
gsp ($/capita)	47994.31	3234.71	44330.00	54964.00
agsec ($/capita)	300.37	60.18	190.92	418.81
unempl (%)	5.86	1.26	4.30	8.10
co2 (tonne/capita)	26.02	3.21	21.25	31.29
nox (kg/capita)	8.58	6.03	0.25	20.98
wateruse (1000tonnes/capita)	561.77	16.16	533.86	593.69

Utah	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	45.51	53.28	0.00	115.19
gsp ($/capita)	41606.00	2034.78	38695.00	45293.00
agsec ($/capita)	192.21	50.09	71.79	263.66
unempl (%)	4.78	1.55	2.60	7.80
co2 (tonne/capita)	25.21	2.51	21.52	29.20
nox (kg/capita)	26.04	5.71	17.98	36.35
wateruse (1000tonnes/capita)	76.35	4.21	69.65	85.38

Vermont	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	4.55	6.12	0.75	14.77
gsp ($/capita)	41150.63	2010.95	36622.00	43127.00
agsec ($/capita)	429.04	84.91	290.90	560.08
unempl (%)	4.33	1.03	2.80	6.60
co2 (tonne/capita)	10.05	0.85	8.78	11.29
nox (kg/capita)	0.78	0.29	0.31	1.61
wateruse (1000tonnes/capita)	12.11	1.17	9.99	13.89

Washington	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	212.90	166.75	0.00	436.31
gsp ($/capita)	52264.06	2424.55	48408.00	55577.00
agsec ($/capita)	531.45	98.69	399.42	695.39
unempl (%)	6.79	1.64	4.70	10.00
co2 (tonne/capita)	11.75	1.19	10.01	14.12
nox (kg/capita)	2.57	1.13	0.99	5.02
wateruse (1000tonnes/capita)	45.06	6.14	27.27	51.82

West Virginia	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	47.65	42.27	0.00	101.87
gsp ($/capita)	34296.25	1563.93	32144.00	36817.00
agsec ($/capita)	45.52	20.95	21.68	85.71
unempl (%)	6.16	1.33	4.30	8.70
co2 (tonne/capita)	57.31	6.04	48.44	65.19
nox (kg/capita)	64.52	48.81	4.79	148.57
wateruse (1000tonnes/capita)	172.53	19.87	142.37	194.46

Wisconsin	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	164.08	147.45	12.59	346.27
gsp ($/capita)	44500.50	1473.71	41911.00	46893.00
agsec ($/capita)	637.06	173.07	377.03	906.86
unempl (%)	5.76	1.55	3.50	8.70
co2 (tonne/capita)	18.30	1.35	15.82	20.14
nox (kg/capita)	9.98	6.10	0.77	20.86
wateruse (1000tonnes/capita)	118.53	3.74	109.20	122.86

Wyoming	**Mean**	**Std. Dev.**	**Min.**	**Max.**
windcap(watt/capita)	1339.97	1009.01	11.92	2522.00
gsp ($/capita)	60269.38	5276.42	50814.00	69182.00
agsec ($/capita)	682.08	150.71	430.91	963.00
unempl (%)	4.33	1.10	2.80	6.40
co2 (tonne/capita)	120.33	5.93	111.73	128.17
nox (kg/capita)	139.27	38.95	82.89	186.19
wateruse (1000tonnes/capita)	90.44	2.42	85.98	97.46

Appendix D. Installed wind energy generation capacities of U.S. states between 2000 and 2015 (total) [4]

windcap **(MW)**	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Alaska	0	0	0	1	1	10	3	3	3	7	7	7	33	60	73	61
Arizona	0	0	0	0	0	0	0	0	0	63	128	138	237	237	237	267
California	7	1597	1741	1943	2037	2038	2257	2318	2371	2653	2786	3742	5493	5618	5833	5741
Colorado	17	51	59	221	227	229	289	1065	1065	1240	1296	1803	2299	2331	2594	2964
Delaware	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2
Hawaii	2	11	11	11	11	11	43	64	64	64	62	92	176	176	176	176
Idaho	0	0	0	0	0	11	75	75	117	146	352	611	967	967	967	967
Illinois	0	0	0	50	50	105	105	740	962	1596	1946	2737	3545	3550	3552	3825
Indiana	0	0	0	0	0	0	0	0	131	1037	1340	1340	1540	1540	1740	1740
Iowa	4	318	416	462	623	820	921	1170	2661	3444	3664	4302	5104	5150	5663	6314
Kansas	0	112	112	113	113	263	363	363	812	1011	1072	1272	2719	2969	2969	3574
Maine	0	0	0	0	0	0	0	42	47	170	266	326	431	431	431	613
Maryland	0	0	0	0	0	0	0	0	0	0	70	120	120	120	160	190
Massachusetts	0	0	0	0	0	0	0	2	2	5	11	31	66	75	84	84
Michigan	1	2	2	2	2	2	2	2	124	143	164	376	876	1161	1530	1530
Minnesota	1	303	338	468	518	687	829	1139	1481	1636	2009	2580	2846	2846	3048	3248
Missouri	0	0	0	0	0	0	0	57	163	309	459	459	459	459	459	459
Montana	0	0	0	0	0	135	145	165	271	375	385	384	643	643	662	662
Nebraska	3	4	3	13	13	73	73	71	71	152	212	333	455	530	812	885
Nevada	0	0	0	0	0	0	0	0	0	0	0	0	150	150	150	150
New Hampshire	0	0	0	0	0	0	0	0	24	24	24	24	171	171	171	171
New Jersey	0	0	0	0	0	0	8	8	8	8	8	8	8	8	9	9
New Mexico	0	0	0	204	264	404	494	494	496	597	700	750	778	778	812	1062
New York	0	18	48	48	48	185	370	425	707	1274	1274	1399	1641	1735	1751	1751
North Dakota	0	0	0	64	64	96	164	383	841	1329	1550	1550	1802	1802	1802	2265
Ohio	0	0	0	4	7	7	7	7	7	7	7	160	462	475	424	432
Oklahoma	0	0	0	176	176	474	594	689	708	1130	1480	1811	3133	3133	3780	5012
Oregon	0	158	183	224	224	299	399	886	1068	1665	2011	2215	3161	3161	3158	3158
Pennsylvania	0	34	34	132	132	132	150	293	361	748	748	789	1344	1344	1344	1334
Rhode Island	0	0	0	0	0	0	0	0	0	0	2	2	2	2	6	6
South Dakota	0	3	3	43	43	43	43	43	193	320	629	780	791	791	660	838
Tennessee	2	2	2	2	29	29	29	29	29	29	29	29	29	29	29	29
Texas	0	925	1085	1286	1286	1846	2738	4340	7281	9234	9808	10367	12185	12326	13998	17662
Utah	0	0	0	0	0	0	0	0	19	222	222	324	324	324	324	324
Vermont	6	6	6	6	6	6	6	6	6	6	6	46	121	121	121	121
Washington	0	180	228	244	244	394	822	1163	1366	2007	2297	2458	2811	2811	3078	3078
West Virginia	0	0	66	66	66	66	66	66	330	330	431	528	583	583	583	583
Wisconsin	23	54	53	53	53	53	53	53	365	449	469	631	636	635	638	638
Wyoming	6	141	141	285	285	287	287	287	680	1104	1415	1432	1433	1433	1433	1433

windcap = 0	4500 < *windcap* ≤ 6750	11250 < *windcap* ≤ 13500
0 < *windcap* ≤ 2250	6750 < *windcap* ≤ 9000	13500 < *windcap* ≤ 15750
2250 < *windcap* ≤ 4500	9000 < *windcap* ≤ 11250	15750 < *windcap* ≤ 18000

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CHAPTER FOUR

WIND ENERGY POLICY DIFFUSION: AN ANALYSIS OF THE MIDWESTERN UNITED STATES

Abstract

The installed wind power capacity in the United States (U.S.) has increased from 2539 megawatts (MW) in 24 states in 2000 to 84413 MW in 41 states according to the most recent data. Since the electricity production from wind power first started in 1980s, the increase in generation capacities has been highly dependent on the adoption and implementation of regulatory policies and financial incentives of state and local governments. The objective of the current study is to examine state- and local-level diffusion of wind energy policies in the Midwestern U.S. from 2008 to 2015 using a random-effects panel data model and following the dynamic modelling of internal and external factors of policy diffusion. We narrow our focus to seven neighboring states, the states of West North Central division, to provide control for external factors (i.e. geographical interdependence). The internal policy diffusion factors considered in this study include wind power potential, per capita gross state product, unemployment rate, per capita value of the agriculture sector, number of establishments in the agricultural sector, and state government control. Through the addition of interaction terms, our analysis also considers the behavioral differences in these regressors under Republican and non-Republican state governance. Our findings suggest that economic development potential is

a common factor of wind energy policy diffusion at both the state- and local-level. Additionally, technical terms and agricultural sector presence provide motives for the state-level diffusion of wind energy policies. The findings on the significance and size of the impact of the internal factors are expected to provide useful guidance to shareholders (i.e. investors and land owners) who may benefit from an increased number of regulatory policies and financial incentives, and enable them to plan more efficiently.

1. Introduction

Supplying over 5.5% of the utility-level electricity of the United States (U.S.) [1], wind power has become a “mainstream” source of energy in the U.S. [2]. With the addition of Connecticut in 2016 and North Carolina in the first quarter of 2017, the number of states with wind energy sourced electricity generation capacity has increased to 41 and the installed capacity for wind power has exceeded 84 gigawatts (GW) in the country [1]. According to the National Renewable Energy Laboratory, the technical capacity for wind power, in other words wind energy supply potential, in the U.S. is over 10000 GW [3]. This capacity can annually generate over 32 petawatt-hours (PWh) [3] which is 8.3 times bigger than the total electricity consumption (3.85 PWh) in the U.S. in 2016 [4].

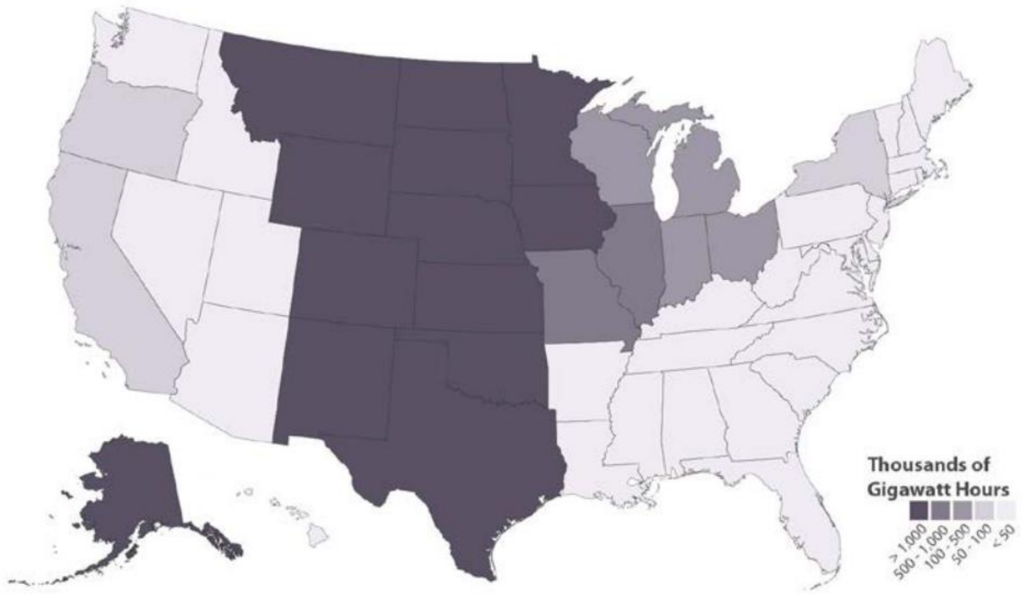
Today, wind energy worldwide is considered a strong substitute for conventional energy sources as a secure, sustainable and environment-friendly option. Switching to wind and other renewables is, in part, an effort to overcome the negative externalities of the increasing consumption of energy around the world [5]. As for the diffusion of renewable energy generally, it is widely agreed upon that the policy environment and enabling structure is crucial for the successful and effective promotion and increased use of wind power [5], [6].

In the U.S., the production of electricity from wind energy has been highly dependent on the structure of the policy environment since the production of wind power sourced electricity first began in the 1980s [7]. The Tax Act of 1980 motivated wind energy investors until 1986 when the tax credits were terminated [7]. Wind power investments accelerated again in 1999, when the extent of production tax credits, under the Relief

Extension Act of 1992, expanded for the wind energy sector [7]. Since 2000, there has also been growing support from state and local governments for increasing the number of policy tools used to deploy wind power across the country such as tax incentives, loan programs, zoning ordinances and wind permitting standards [8].

The current study utilizes the increasing number of wind energy policy tools as a proxy for diffusion and uses random-effects panel data model to provide additional depth to our knowledge on the factors related to wind energy policy diffusion from 2008 to 2015. Our focus is the seven Midwestern U.S. states, which are located in the center of the wind energy corridor of country (Figure 1). The states in this region include Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

Figure 1: Total estimated technical potential for onshore wind power in the U.S. [3]



2. Literature Review

Over the past several decades, public policy literature on policy diffusion across states and nations has been growing. This literature focuses on the breadth of policy diffusion, including factors of the policy transfer processes, agents involved, and structures followed (voluntary, coercive, and mix). Even though terminology and focus often vary, policy diffusion, policy transfer, policy convergence, or lesson-drawing, all relate to a mechanism in which "knowledge about policies, administrative arrangements, institutions, etc. in one time and/or place is used in the development of policies, administrative arrangements, and institutions in another time and/or place" [9], [10].

The early studies of policy diffusion emerged as a subset of comparative politics beginning in the 1960s. These studies explained the diffusion process of policies primarily by geographical interactions and learning from early adopters [9]. For instance, a study conducted by Walker (1969) focused on the adoption of innovations among the U.S. states and considered the adoption of policies by another state as a reference point for the diffusion of state-level innovation policies [11]. In the 1980s, critiques emerged on the comprehensiveness of these early studies by stating that the objective of these was not really the process but only the substance [12], thus the mechanisms of the transfer – with a special focus on the agents involved – became the new focus of policy analysts. The identification of the rational political actors who examine the "successful" policies implemented elsewhere and who are involved in the adoption of the same policies within another political structure was the main concentration of scholars from the 1980s until the early 1990s [9]. In their systematic literature review, Dolowitz and Marsh (1996) identified these actors in six main categories: “elected officials [8]; political parties [13]; bureaucrats/civil servants [14]; pressure groups [15]; policy entrepreneurs/experts; and supra-national institutions” [16].

Two mainstream approaches have emerged in the field of policy diffusion since the 1990s. The approach developed by Dolowitz and Marsh (2000) presents a systematic and comprehensive framework including types of transfer (voluntary, coercive or mix), agents involved (elected officials, bureaucrats, institutions, ideologies…), extent of diffusion (within-the-nation or cross-national), degree of diffusion (copying, emulation, mixtures or inspiration), constraints on diffusion (policy complexity, existing infrastructures, technology…) and possible failures of diffusion (incomplete transfer, inappropriate transfer…) [10]. The policy diffusion framework of Dolowitz and Marsh (2000) offered a practical tool in the area of comparative politics, especially to evaluate the diffusion of a specific policy type between two political structures (i.e. cities, counties, stats…). On the other hand, the dynamic elements of diffusion were first investigated by the empirical study of Berry and Berry in 1990 [16]. In their analysis, the authors included both internal (political, economic, and social) and external (regional influences) factors of policy diffusion [16]. The two aspects of policy diffusion – internal and external – have been considered key elements in diffusion studies that have followed.

In the area if international policy, a policy diffusion theory was first used in 1989 by Haas [17]. In his study, Haas investigated internal and external factors of the Mediterranean Action Plan and suggested that international learning was as important as the domestic factors in developing common environmental policies in the (Mediterranean) area [17]. Following Haas's study, a robust literature has emerged around policy diffusion and related environmental policies, including environmental policy instruments (see, e.g. Frank et al. (2000), Tews et al. (2003), Holzinger et al. (2008)), international environmental policies (see, e.g. Neumayer (2002), Bernhagen (2008), Schulze and Tosun (2013)), and climate change policies (see, e.g. Bursh (2010), Massey et al. (2014), Biesenbender and Tosun (2014)) [18]–[26].

In recent years, internal and external elements of policy diffusion have also been used to explain the diffusion of renewable energy policy. In the existing literature on the diffusion of renewable energy policies, external factors were consistently found to be significantly related to the diffusion of policies [27]–[31]. Focusing on the period between 1997 and 2008 for 34 U.S. states, Chandler (2009) tested the significance of internal considerations as well as neighboring and regional impacts on the diffusion of Sustainable Energy Portfolio Standards. His analysis revealed that policy diffusion primarily resulted from external factors (that includes neighboring and regional impacts), even accounting for an ideological distance with previous adapters [27]. Strebel (2011) examined the diffusion process of sub-national energy policies in Switzerland from 1990 to 2007 and concluded that the internal determinants were not sufficient explanations and intergovernmental institutions promote diffusion only externally and under certain circumstances (e.g. relative advantage and observability) [28]. Stadelmann and Castro (2014) focused on revealing the domestic (internal) and international factors of the diffusion of four types of renewable energy support policies (i.e., renewable energy targets, feed-in tariffs, framework policies and other financial incentives) in 112 countries from 1998 to 2009 [29]. The results of their analysis presented stronger support for the interaction among colonial peers and membership within the EU compared to domestic (internal) factors [29].

Schaffer and Bernauer (2014) investigated the diffusion of feed-in tariffs and green certificate schemes in 26 International Energy Agency member countries between 1990 and 2010, and examined both domestic (internal) and international (external) elements [31]. Their findings suggested that in addition to the external factors (European Union membership), internal factors (characteristics of the existing energy supply system and federalist structure of the political system) were significantly related to the diffusion of renewable energy policies as well [31]. Similarly, the findings of Nicholson-Crotty and Carley (2016) focused on the diffusion of renewable portfolio standards in 50 U.S. states from 1997 to 2009 and demonstrated that not only external factors, but also the implementation environment (an internal element) played an important role in the diffusion process of energy policy [30].

The internal factors of policy diffusion have also been the focus of Laird and Stefes (2009), who analyzed the source of differences in the diffusion of renewable energy policies in Germany and the U.S. Their findings revealed the importance of internal – country-specific institutional and social – factors, as well as the path dependency of historical events for the diffusion of renewable energy policies within these countries [32]. Similarly, the wind energy sector specific study of Wiener and Koontz (2012) explained the diffusion of wind energy policies in 44 U.S. states with five important internal elements including “commitment to environmental protection and policy innovations, citizens ideology, per capita wealth, energy policy network communications, and desire to be viewed as an environmental leader" [33].

The current study recognizes the importance of regional influences and focuses on a specific region, the Midwestern section of the U.S. The area is also considered the wind energy corridor of the U.S. (Figure 1). In the next section, we will define wind energy specific characteristics of the area.

3. State Wind Energy Profiles

The West North Central region of the U.S. (i.e., Iowa, Kansas, Nebraska, Minnesota, Missouri, North Dakota, and South Dakota) is located in the center of the country's wind tunnel where the best onshore wind resources are located (Figure 1). 20% of the nation's wind turbines (n=12242) are located in this region of the country (Table 1). These wind turbines also constitute 25% of the nation's installed wind capacity (21192 megawatts (MW)) (Table 1). According to the latest State Fact Sheets of American Wind Energy Association (2017), this region includes two of the leading wind energy generation states. Iowa is the leader in percentage energy generation from wind power (36.6%). North Dakota is the leader in per capita wind energy generation (equivalent of 0.99 U.S. homes powered per capita) (Table 1). Similarly, the benefits of the wind energy sector to the West North Central's economy have been substantive. There are 56 wind manufacturing facilities in the West North Central region and the industry creates over 25000 jobs (Table 2). In 2016, the total annual land lease payments were over 48 million dollars in the West North Central region and per state annual land lease payment amounts for the installation of wind turbines was either equal to the U.S. average or above the U.S. average ($1-5 million) (Table 2).

Table 1. Wind energy generation characteristics in the West North Central region (2017) [1]

	Installed wind capacity (MW)	Number of wind turbines	Wind Energy Generation		
			Percentage of in-state energy production	**Equivalent number of U.S. homes powered**	**Per capita equivalent of U.S. homes powered**
Iowa	6952 (2nd)	3965 (3rd)	36.6% (1st)	1850000 (2nd)	0.5902 (3rd)
Kansas	4931 (5th)	2741 (5th)	29.6% (3rd)	1300000 (5th)	0.4472 (5th)
Minnesota	3499 (7th)	2327 (7th)	17.7% (6th)	983000 (7th)	0.1781 (10th)
Missouri	659 (24th)	349 (25th)	1.4% (31th)	104000 (26th)	0.0171 (30th)
Nebraska	1328 (18th)	741 (17th)	10.1% (14th)	351000 (16th)	0.1840 (9th)
North Dakota	2846 (11th)	1536 (11th)	21.5% (5th)	747000 (9th)	0.9856 (1st)
South Dakota	977 (19th)	583 (19th)	30.3% (2nd)	291000 (19th)	0.3362 (6th)
U.S. Average	**1680**	**1269**	**6.87%**	**537251**	**0.1132**

**State rankings in 50 states are given in parentheses when available.*
***Darkened cells indicate the values above U.S. average.*

Table 2. Economic benefits of wind power in the West North Central region (2016) [1]

	Number of direct and indirect jobs supported by wind industry	**Number of wind manufacturing facilities**	**Total project investment ($)**	**Annual land lease payments ($)**
Iowa	8001 to 9000	11 (10th)	13.5 billion (2nd)	20-25 million
Kansas	5001 to 6000	5 (16th)	8.4 billion (6th)	10-15 million
Minnesota	3001 to 4000	20 (6th)	6.8 billion (7th)	10-15 million
Missouri	1001 to 2000	11 (10th)	1.4 billion (22th)	1-5 million
Nebraska	3001 to 4000	0 (21st)	2.4 billion (17th)	1-5 million
North Dakota	4001 to 5000	4 (17th)	5.4 billion (11th)	5-10 million
South Dakota	1001 to 2000	5 (16th)	2.1 billion (19th)	1-5 million
U.S. Average	**2000 to 3000**	**10**	**3.2 billion**	**1-5 million**

**State rankings in 50 states are given in parentheses when available.*
***Darkened cells indicate the values above U.S. average.*

Each state has different wind energy characteristics and different policy measures in place related to wind energy production. In the first quarter of 2017, Iowa produced 36.6% of its electricity from wind energy and was the U.S. leader in the share of wind power in the state’s energy portfolio (Table 1). For the same time period, the state was ranked second in terms of installed wind power capacity (6952 MW) and wind power generation (equivalent of 1850000 U.S. homes powered), and third in the number of wind turbines (n=3965) (Table 1). According to the Iowa Office of Energy Independence, oversaturated transmission lines were the biggest barrier to the additional installation of wind turbines in the region [34]. In 2016, Iowa was not a national leader in the number of wind manufacturing facilities (n=11) but across wind energy operations, construction and manufacturing, the wind industry employed between 8000 - 9000 jobs in the state (Table 2).

Kansas has the second largest technical wind energy potential in the country with over 952000 MW of estimated wind resources. Kansas already exceeded the expectations of Governor Sebelius who, in 2007, stated that the goal was to produce 20 percent of the state's electricity from wind power by 2020 [35]. The state became the third largest producer in the nation, with 29.6% of its electricity produced from wind energy (Table 1), while increasing the installed wind capacity from 114 MW in 2001 [4] to 4931 MW in 2017 (Table 1). During the first three months of 2017, Kansas was also among the top five states for installed wind energy capacity (1931 MW), number of wind turbines (n= 2741) and electricity generation from wind power (equivalent of 1300000 U.S. homes powered) (Table 1). In 2016, there were 5 manufacturing facilities in Kansas and the wind industry offered more than 5000 jobs throughout the state (Table 2).

Ranking sixth in the nation, Minnesota produced 17.7% of its electricity from wind energy during the first quarter of 2017 (Table 1). For the same period, the state was also considered among the top seven states in the country for its installed wind capacity (3499 MW), number of wind turbines (n=2327) and total amount of wind powered electricity (equivalent of 983000 U.S. homes powered) (Table 1). Minnesota had the highest number of wind manufacturing facilities in the region (n=20) and the industry offered more than 3000 jobs in 2016 (Table 2). The number of wind turbines, as well as the share of in-state energy generated by wind power, is expected to increase after the completion of the CapX2020 project, which aims to improve the transmission grid infrastructure (capacity) in Minnesota and the surrounding region (including North Dakota, South Dakota and Wisconsin) [36].

Missouri started producing electricity from wind only in 2008 and as such has the lowest technical potential in the region (Figure 1). In the first quarter of 2017, the installed wind energy capacity (659 MW), the number of wind turbines (n=349) and the electricity generation from wind power (equivalent of 104000 U.S. homes powered) were below the national averages (Table 1). Regardless, Missouri has successfully attracted investment for wind manufacturing due to its geographic proximity to key wind energy resources [37]. By 2016, the state had 11 wind manufacturing facilities and was the second in the region for wind manufacturing (Table 2).

Nebraska has the highest estimated technical wind energy potential in the nation, after Texas and Kansas (Figure 1). Nevertheless, the state’s wind energy potential remains mostly unused with only 741 installed wind turbines and 1328 MW of installed wind energy generation capacity in 2017 (Table 1). The state produced 10.1% of its electricity from wind in the first quarter of 2017, which is higher than the nation’s average (6.87%) (Table 1). According to the American Wind Energy Association, the electricity produced from wind power in Nebraska saved customers $1.2 billion in 2013 and this amount still continues to increase [38]. Even though this sector is smaller than in neighboring states, in 2016, the wind energy sector employed more than 3000 individuals, although there were no manufacturing facilities (Table 2). However, this number is expected to increase with the addition of new wind turbines as well as manufacturing facilities [2].

In 2017, North Dakota is the leader in the U.S. in per capita wind power sourced electricity generation (Table 1). In the first quarter of 2017, per capita equivalent of U.S. homes powered by wind energy in North Dakota was 0.99 whereas the closest per capita electricity generation value for wind power was only 0.69 in Wyoming [1]. Wind energy's share of in-state electricity production was 21.5%, with 1536 wind turbines and 2846 MW of installed wind capacity in North Dakota. The state is also known for its favorable wind conditions creating high capacity factors for wind energy generation. The wind capacity factor for North Dakota ranges from 42% to 44% [39], compared to the U.S. average which is below 35% in 2016 [40]. After Iowa and Kansas, North Dakota offers the highest number of jobs in the wind industry in this region. In 2016, the total number of employees in the wind industry was more than 4000 (Table 2). By 2016, there were also four wind manufacturing facilities in North Dakota (Table 2), creating more than 1000 of the jobs in the industry [39].

The final comparison state in the region, South Dakota, produces 30.3% of its electricity from wind energy and has the second highest percentage of in-state energy production in the nation in 2017 (Table 1). However, the state is the 19th in nation for installed wind capacity (977 MW), number of wind turbines (n=583) and total amount of the wind powered electricity generated (equivalent number of U.S. homes powered =

291000) (Table 1). As in the case of Minnesota, the development of wind farms is constrained by the overuse of transmission lines and the CapX2020 project aims to improve this infrastructure for the industry in e upcoming years [41]. By 2016, there were five wind manufacturing facilities and there were more than 1000 jobs in the wind industry in South Dakota (Table 2).

This review of these wind energy characteristics provides a brief look at the scope and scale of production, distribution and impacts from wind energy in this region. The wind energy potential in the states of the West North Central region is above average (Figure 1) and some of these states are leveraging this potential to a much greater extent than others. There is increasing evidence that these types of changes in an economy occur, in part, due to the enabling policy, regulations, and related infrastructure that lays foundation for the technology to spread. Analyzing the potential for policy diffusion across the states is an important mechanism for understanding this process. The next section will explore the determinants of the diffusion of wind energy policy that the current study considers.

4. Determinants of wind energy policy diffusion

4.1. Technical capacity

Literature suggests that wind energy potential of a region has a significant and positive relationship with the share of renewable energy in a state's energy portfolio in 48 U.S. states from 1990 to 2008 [42]. In addition, investment decisions of related business sectors are negatively influenced by the regulatory uncertainties of policy reversals or political uncertainty in the industry [43]. Thus, a stable and predictable policy environment is indispensable for the development of renewable energy source [43]. Accordingly, in the current study, which focuses on the wind energy leader states of the U.S. that are located in the country's wind energy corridor, we expect there to be a positive relationship between the technical capacity of wind energy and the diffusion of wind policies.

4.2. Economic factors

The literature on renewable energy and environmental issues more broadly suggested a positive bilateral relationship between the level of income and environmental expectations. As such, we can assume that the demand for environmental goods (e.g. clean air and water) are positively associated with an increase in state income level [44], along with income per capita [45]. This relationship also holds for environmental legislation: Chandler (2009) suggested that per capita income is positively associated with the adoption of renewable portfolio standards for 34 U.S. states from 1997 to 2008 [27]. Higher income levels allow states to bear the cost of renewable energy technologies and regulatory policies [46]. Therefore, in the current study, we also expect that gross state product per capita (as a proxy for state income level) and the diffusion of wind energy policies have a significant and positive relationship.

Likewise, unemployment was considered another important factor in the renewable energy literature and was found to be related to an increase in renewable energy deployment [47], [48]. Wind power is expected to create new jobs in states without resulting in any corresponding loss of jobs or environmental impacts. In addition, strong policy inducement plays an important role in the development of wind power [49] and the corresponding employment and economic spillovers. Therefore, in the current study, we expect that as a state’s unemployment rate increases, there is a positive association with an increased number of supportive policies facilitating wind energy diffusion across the state.

4.3. Agricultural industry presence

This research is focused on the states of the Midwestern U.S. where the agricultural sector is a substantive part of these state economies. Because of this, this research expects the agricultural sectors presence to be significantly related to the diffusion of wind energy policy in the West North Central region of the U.S. In addition to the importance of the agricultural sector, wind-powered electricity generation involves a significant amount of land, and wind farms are, in part, located on agricultural land areas [50]. Additionally, leasing their land for wind power offers a new source of income for the agricultural industry [50]. The current study, therefore, expects that agricultural income is positively related to wind energy legislation providing supportive policy for the development of wind energy in the region. Similarly, an independent variable for establishments in agriculture is included in the current study to capture the importance of farming scale in leveraging wind energy production. We expect there is a positive relationship between the number of the farming establishments and wind energy policy diffusion.

4.4. Political factors

Since the 1970s, when environmental issues were seen as a unifying force of “the reactionary right and the revolutionary left” [51], the ideological gap between Republicans and Democrats on pro-environmental legislation has increasingly widened [52], [53], although some suggest that regardless of party affiliation, individuals in the U.S. are supportive of the development of alternative energies over fossil fuels [54]. Scholars have frequently investigated the partisan divide among Republicans and Democrats on environmental attitudes and suggested a significant relationship between party affiliation and pro-environmental attitudes [52], [53], [55]–[59]. In the literature, Republicans and conservatives were found to be less environmentally aware and concerned about environmental issues [52], [53], [60]–[65]. This is argued to be the result of the associated negative consequences of pro-environmental attitudes on business and industry [56], [66]. However, these judgments have not always been consistent. Dell (2009) reconsidered the idea of "Republican moments" of Pope (1990), and claimed that the Republicans have been involved in pro-environmental policy-making following visible tragedies (e.g. the asbestos contamination in Lilly, Montana, and the nuclear accident at the Three Mile Island Nuclear Generating Station in Dauphin County, Pennsylvania) but did not contribute to an understanding of the root cause behind tragedies [67], [68]. Similarly, Coley and Hess (2012) investigated the differences in support for state-level green energy legislation between Democrats and Republicans in 22 U.S. states from 2007 to 2011, and suggested that Republicans supported renewable energy laws where "median household income is lower, environmental organizations are weaker, labor-environmental coalitions are absent, and the proportion of Democrats in the legislature is lower" [62].

In the current study, state government control is represented by party control, meaning that either Republicans or non-Republicans (Democrats, mixed, or unicameral) control state government, inclusive of the governor and legislature. We expect that Republican governors and legislatures consider wind energy legislation a business opportunity in these states, rather than a fiscal burden on the resident, and that Republican, state government control is positively related to the diffusion of wind energy policies.

4.5. Interaction terms

The presence of a significant interaction term indicates that the effect of one predictor variable on the response variable is different at different values of the other predictor variable [69]. Thus, including interaction terms with the state government control dummy allows the current study to consider the behavioral differences in the main regressors, including wind power potential, per capita gross state product, unemployment rate, per capita value of the agriculture sector and number of the establishments in agricultural sector under Republican and non-Republican control of states. Republican ideology is assumed to be aligned with business interests [62], therefore we expect that (i) the interaction between wind power potential and Republican state control is significant and positively contributes to the development of the wind industry through the diffusion of wind energy policies. We further assume that the interaction between the economic variables and Republican state control are significant and positively linked to the diffusion of wind energy policies due to the bilateral relationship between the wealth of the states and creation of a new energy industry. While, finally the interaction between the agricultural sector presence and Republican state control is assumed to be significant and positively related to the state's wind energy policy diffusion because it is a prominent sector in the region with existing business relations between this sector and the state government. Further, there are opportunities to leverage wind energy as an additional income source for agricultural land owners.

5. Methods

5.1. Study Period and Data Description

The current study covers the period from 2008 to 2015. The years prior to 2008 are not included in the study because Missouri started producing wind sourced electricity in 2008 and therefore did not have electricity production from wind energy before 2008 [70]. The start year is additionally important for two primary reasons: (i) the economic recession following the global financial crisis in 2008 also impacted the economies of U.S. states, resulting in behavioral changes in state budgetary allocations and fiscal health [71], and (ii) the ideological gap between the Democrats and Republicans on "green energy" grew over the Presidency of Barack Obama [62], [72]–[74]. Except for each states' wind energy characteristics that were reported in 2017 [1], no data were available after 2015.

Detailed information on the variables including unit, definition and the source is provided in Table 3 (see Appendix A and Appendix B for descriptive statistics). The current study considers the aggregated number of effective state and city/county level wind energy policies yearly, for the years between 2008 and 2015, as a proxy for regional diffusion of wind energy policy at state- and at local-levels, respectively (Appendix C and Appendix D present the detailed list of state- and local-level policies, respectively). A thorough review of these policies allowed us to determine which policies were supportive of wind energy and could be argued to facilitate wind energy diffusion across the state. All of the policies utilized in the analysis are assumed to be proactive policies that would support the diffusion of wind energy.

Table 3. Variable description

Variable	Unit	Definition	Source
statepol	number	Wind energy supporting policies and incentives at state-level	"Database of State Incentives for Renewables & Efficiency" by North Carolina (N.C.) State University, N.C. Clean Energy Technology Center [75]
localpol	number	Wind energy supporting city and county ordinances	"Wind energy ordinances" by the U.S. Department of Energy – WINDExchange [76]
windpot	gigawatt hours (GWh)	Annual wind resource technical potential at 80 meters	"U.S. Renewable Energy Technical Potentials: A GIS Based Analysis" by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, National Renewable Energy Laboratory [3]
gsp	\$1000/capita	Gross state product (per capita)	"Annual Gross Domestic Product (GDP) by State" by the U.S. Department of Commerce - Bureau of Economic Analysis [77]
unempl	Percentage (%)	Unemployment rate	"States: Employment status of the civilian non-institutional population, 1976 to 2016 annual averages" by the U.S. Department of Labor - Bureau of Labor Statistics [78]
valofagr	\$1000/capita	Value added to U.S. economy by agricultural sector (per capita)	"Correlates of State Policy" by the Michigan State University - Institute for Public Policy and Social Research [79]
estinagr	per mille (‰)	The ratio of the number of establishments in the agricultural sector over total number of establishments for all sectors	"Community Facts" by the U.S. Census Bureau [80]
rstategov	dummy	State government control inclusive of governor and	"Book of the States" by the Council of State Governments [81]

		legislature (dummy: 1 if Republican, 0 if democrat, mixed, or unicameral)	

All variables, with the exception of wind energy potential which is assumed to be constant, vary over time (see Appendix B). The data on gross state product and value-added by the agricultural sector to the U.S. economy were normalized using the population statistics provided by the U.S. Census Bureau [82], [83]. State government control is represented with a dummy variable. A state government control dummy variable is equal to one when the state government, inclusive of the governor and legislature, is Republican, and is equal to zero when the state government is non-Republican (i.e., Democrat, divided, and other). For the study period, Republicans have had control the most (e.g., 39% or n=22 of the state government data represents Republican control) (Table 4).

Table 4: State government control in the West North Central (2008-2015) [81]

	Iowa	**Kansas**	**Minnessota**	**Missouri**	**Nebraska**	**North Dakota**	**South Dakota**
2008	Democrat	Divided	Divided	Republican	Other	Republican	Republican
2009	Democrat	Divided	Divided	Divided	Other	Republican	Republican
2010	Democrat	Divided	Divided	Divided	Other	Republican	Republican
2011	Divided	Republican	Divided	Divided	Other	Republican	Republican
2012	Divided	Republican	Divided	Divided	Other	Republican	Republican
2013	Divided	Republican	Democrat	Divided	Other	Republican	Republican
2014	Divided	Republican	Democrat	Divided	Other	Republican	Republican
2015	Divided	Republican	Democrat	Divided	Other	Republican	Republican

5.2. Empirical Model

The objective of the current study is to examine the relationship of a number of technical, economic, agricultural sector-specific and political variables with wind energy policy diffusion at the states level in the West North Central region of the U.S (i.e.,Iowa, Kansas, Nebraska, Minnesota, Missouri, North Dakota and South Dakota). Through the addition of interaction terms to the analysis, this study also considers the behavioral differences in regressors under Republican and non-Republican state governance.

In order to identify the factors of wind energy policy diffusion at the state- and local-level, we use random-effects panel data regression analysis and consider the following empirical model:

$$policydiffusion_{it} = b_1 windpot_{it} + b_2 gsp_{it} + b_3 unempl_{it} + b_4 valofagr_{it} + b_5 estinagr_{it} + b_6 rstategov_{it} + b_7 windpot_{it} * rstategov_{it} + b_8 gsp_{it} * rstategov_{it} + b_9 unempl_{it} * rstategov_{it} + b_{10} valofagr_{it} * rstategov_{it} + b_{11} estinagr_{it} * rstategov_{it} + a_i + u_{it},$$

where *policydiffusion* represents either *statepol* or *localpol*, $i = 1, \ldots, N$ represents each state in the panel (N=7) and $t = 1, \ldots, T$ refers to the time (T=8). *b1* to *b11* represents the coefficients that the model estimates for the explanatory factors that are presented in Table 3 (*windpot*, *gsp*, *unempl*, *valofagr*, *estinagr*, and *rstategov*) as well as for the interactions of technical (*windpot*), economic (*gsp* and *unempl*), agricultural sector specific (*valofagr* and *estinagr*) factors with the state government control (*rstategov*). a_i and u_{it} denote state-specific fixed effects and idiosyncratic errors, respectively. In addition to linearity in predictors, the assumptions of panel data analysis, include (i) no perfect collinearity, (ii) strict exogeneity, (iii) homoskedasticity, (iv) no serial correlation and (v) normality. These were verified prior to the analysis (see Appendix E for the full list of assumptions as well as their definitions, test methods, Stata codes and results) [84]. The only assumption that the models failed to satisfy was no serial correlation, therefore models were corrected for serial correlation prior to the estimation.

The focus of the current analysis is seven Midwestern U.S. states with non-uniform installed wind energy capacities. In the current study, panel data analysis allows for flexibility in modeling differences in behavior across individual states [85]. Statistically, data for the individual states also help to minimize multicollinearity problems, which can be related to the use of macro level data [86]. Public policy analysts assume that a model cannot consider all important characteristics of a cross-sectional unit and leaves out important factors which are related to the existing parameters of the model, therefore use fixed-effects panel data regression analysis [84]. Nevertheless, fixed-effects model is not suitable to estimate the coefficients for time-invariant factors because the model takes first order differences which removes all time invariant factors. Due to the current study's assumption on the time-invariant characteristic of one of the key explanatory variables (*windpot*), random-effects panel data model was preferred and used in our study. Therefore, in addition to the typical assumptions of panel data analysis, the current study assumes that the unobserved characteristics of the states (such as geographic features or historical factors) are uncorrelated with existing explanatory variables of the model [87]. A significance level of 0.05 was used for all tests of significance.

6. Results and discussion

The descriptive statistics, including means, standard deviations, minimums and maximum, for the 7 focus states and for variables which are used for empirical analysis of the wind energy policy diffusion in the Midwestern U.S. are presented in Appendix A and B, respectively.

The statistics suggest that, over the study period, legislative support for wind energy deployment increased in the West North Central region of the U.S. The mean values for the number of pieces of legislation at the state and city/county level illustrate a continuous increase between 2008 and 2015. The average number of state-level legislative efforts increased from 6.14 to 9.57 and the average number at the local level increased from 2.14 to 15.43 from 2008 to 2015. For the study period, Minnesota and Kansas (except for 2009) represent the states with the highest and the lowest number of state-level wind energy policies, respectively. Likewise, Minnesota had the highest number of city/county level wind energy ordinances from 2010 to 2015, whereas North Dakota and Missouri had the lowest number of wind energy ordinances from 2008 to 2012 and from 2013 to 2015, respectively.

The entire West North Central region is considered part of the U.S. wind energy corridor, with an average annual wind resource technical potential of 2199163 Gwh. The state of Kansas has the most technical wind energy generation potential at 3101576 Gwh annually.

The mean per capita values for gross state product presents an overall increasing trend in this region over the study period, except in 2009 and in 2015, when there was a slight decrease in the mean. North Dakota had the highest mean per capita gross state product,($60075.63), related to the Bakken Shale Oil Boom beginning in 2010 [88], whereas all other states' mean per capita gross state product varied between $42341. 25 and $51349.63.

The data illustrate a significant increase in unemployment levels in the region in 2009. Compared to 2008, the mean unemployment rate increased from 4.27% to 6.29%, the minimum unemployment rate increased from 3.10% to 4.10% and the maximum unemployment rate increased from 6.10% to 9.30% in 2009. The mean unemployment rate in the region was back to its pre-2009 levels in 2014. For the study period, North Dakota had the lowest unemployment rates and Missouri had the highest average unemployment rates, 3.25% and 7.30% respectively.

There is no upward or downward trend in the mean agricultural income or in the number of establishments in the agricultural sector between 2008 and 2015. For the study period, the average contribution of the agricultural sector to the national economy was the highest in South Dakota and the lowest in Missouri; and North Dakota and South Dakota had the highest share of establishments in the agricultural sector with 5.17‰ and 5.10‰, respectively, whereas Missouri had the lowest with 1.70‰.

The state government control in the study region has been consistently Republican for North Dakota and South Dakota over the 2008 to 2015 study period, whereas non-Republican, including Democrat and mixed legislative and governorships, have occurred in Iowa, Minnesota and Nebraska. Kansas and Missouri had both Republican and non-Republican state government control over the study period.

Table 4 and 5 present the regression results of the factors associated with wind energy policy diffusion in the Midwest region of the U.S. from 2008 to 2015. Two models of policy diffusion are considered, one for state-level policies and another for local-level policies.

Table 5. Random-effects panel data regression analysis coefficients, standard errors, and p-values for state-level diffusion of wind energy policy

Independent variables	Coefficient Estimates	Standard Errors	P-values
windpot (1000000Gwh)	-3.069	0.571	0.000*
gsp ($1000/capita)	0.511	0.171	0.003*
unempl (%)	1.076	0.446	0.016*
valofagr ($1000/capita)	-0.632	0.439	0.150
estinagr (‰)	5.520	1.027	0.000*
rstategov	20.859	13.027	0.109
*windpot * rstategov*	1.933	1.202	0.108
*gsp * rstategov*	-0.352	0.232	0.129
*unempl * rstategov*	0.377	0.910	0.679
*valofagr * rstategov*	1.448	0.760	0.050*
*estinagr * rstategov*	-5.538	1.361	0.000*
Intercept	-30.450	9.051	0.001*
Dependent variable:** statepol **(*denotes significance at 5% significance level)			

Table 6. Random-effects panel data regression analysis coefficients, standard errors, and p-values for local-level diffusion of wind energy policy

Independent variables	Coefficient Estimates	Standard Errors	P-values
windpot (1000000Gwh)	1.299	1.173	0.280
gsp ($1000/capita)	0.740	0.350	0.042*
unempl (%)	2.353	0.917	0.009*
valofagr ($1000/capita)	1.234	0.901	0.174
estinagr (‰)	1.944	2.110	0.367
rstategov	34.449	26.766	0.203
*windpot * rstategov*	1.001	2.470	0.682
*gsp * rstategov*	-0.556	0.476	0.256

*unempl * rstategov*	-0.425	1.870	0.818
*valofagr * rstategov*	-0.231	1.561	0.881
*estinagr * rstategov*	-3.064	2.797	0.275
Intercept	-53.795	18.597	0.005*
Dependent variable: localpol ***(*denotes significance at 5% significance level)***			

Two of the interaction terms, interaction between the value of the agricultural sector and Republican state government as well as the interaction between the number of the establishments in the agricultural sector and Republican state control, were found to be statistically related to a state's wind energy policy diffusion in this region from 2008 to 2015. In addition, wind energy potential, per capita gross state product, the unemployment rate, and the number of establishments in the agricultural sector were found to be statistically significant factors of state-level wind energy policy diffusion.

Even though the West North Central region is in the middle of the wind energy corridor of the U.S., results suggest there is a negative relationship between wind potential and the number of policy measures at the state-level. Likewise, the state with the highest wind energy potential has the lowest number of state-level wind energy policy measures. The results suggest that from 2008 to 2015, in this region of the country, the states with lower wind energy potential may consider the wind energy capacity in the region as a window of opportunity for green economic development and therefore, establish a more favorable and predictable investment plateau for the industry through wind energy legislation.

As expected, economic indicators, including per capita gross state product and unemployment rate, are positively associated with the diffusion of wind energy policies in the states regardless of the state government control. Holding all other variables constant, an additional $1000 increase in per capita state income is related to a 0.5 unit increase in the number of wind energy policies adopted by a state. Likewise, holding all other variables constant, an additional 1% increase in the unemployment rate is related to a 1.1 unit increase in state's wind energy policy initiatives. This relationship may provide additional evidence of the value states see in leveraging this industry for economic development potential and related employment benefits.

Agricultural sector presence was found to be a significant factor for wind energy policy diffusion in the region when a state was under Republican government control. From 2008 to 2015, when the state government control was Republican, the per capita value added to the U.S. economy by the agricultural sector was found to be positively related to the number of wind energy supporting policies in the region. As previously stated, this region is geographically ideal for wind powered electricity production and with farmers and landowners able to lease their land for wind turbines, this creates a new source of income for farmers and ranchers in these states. Our results suggest that, under Republican governance, and with potential opportunities for additional sources of individual and state revenue, there is a potential policy window creating demand for additional legislation in support of wind energy legislation and policy efforts. On the other hand, in the analysis, the number of establishments in the agricultural sector was found to be negatively associated with the diffusion of wind energy policies under Republican governance. Assuming that the share of the land area that is used for farming or ranching purposes has not changed over time, a decrease in the number of establishments would result in bigger land share per owner. Given the importance of this industry to these state economies, we assume that land owners that have more power may have stronger influence on state and local governances.

In contrast, under non-Republican government control, the only agricultural sector specific factor which was found to be significant was the number of agricultural establishments. This factor is positively related to the number of state-level wind energy policies. Again, assuming the share of the land area that is used for farming or ranching purposes has not changed over time, an increase in the number of establishments would result in smaller land share per owner. Our results suggest a negative relationship between the land share per agricultural establishments and the number of wind energy policies adopted by non-Republican state governments. The relationship between the number of establishments and the diffusion of wind energy policy presents contrasting results under Republican and non-Republican state government control and suggests that the state level support to the wind energy deployment varies when the agricultural sector constitutes a larger or smaller share of the overall economic base of the state. The exploration of the reason behind the contrasting result on the relationship between the number of establishments and the wind energy policy diffusion will be considered in future research.

The financial crisis in 2008 was argued to be the worst since the Great Depression of the 1930s. When the motivation of city and county councils is suggested to be purely economic, it is easier to understand the 600% increase (from 2.14 to 15.43) in the average number of city/county level wind energy policies during the 8 years following this important economic recession. Kansas has been the leader in the field with the first city level ordinance adopted in 1989 by Sedgwick City Council. The state was also the leader in the number of effective policies in 2008 and 2009. Beginning in 2010, Minnesota became the new leader in the region for local wind ordinances. From 2010 to 2015, in Minnesota, the number of cities and counties that adopted wind energy ordinances increased from 11 to 27.

At the local level, economic variables, including gross state product per capita and unemployment rate, were the only factors significantly related to wind energy policy diffusion. The statistical insignificance of all remaining variables, including the interaction terms, suggests that the main motivation of city and county councils may be focused on the economic development potential of wind energy, and any ordinances passed are likely related to this effort.

7. Conclusion

The current study investigates the internal factors of the increase in policy support by state and local governments for the deployment of wind energy in seven Midwestern U.S. states from 2008 to 2015. Our findings suggest that the economic considerations, including per capita gross state product and unemployment rate, were significantly and positively related to the diffusion of wind energy policies both at the state- and local-level. No other factor was found to be significant at the local level. At the state-level, in addition to the economic factors, two interaction terms (the interaction between the value of the agricultural sector and state government control and the interaction between the number of establishments in the agricultural sector and state government control), the wind energy potential, and the number of establishments were also found to be significant. Despite our expectations, wind energy potential was found to be negatively associated to the diffusion of wind energy policies in the focal states. The contribution of the agricultural sector to the national economy was found to be positively related, and the number of establishments in the agricultural sector was found to be negatively related to wind energy policy diffusion at the state-level under Republican governance. When the state governmental control was non-Republican, the only other variable of significance, in addition to the technical and economic variables, was the number of establishments in the agricultural sector which was positively associated to wind energy policy diffusion at the state-level. The current study adds to the literature by defining the relationship between the economic and agricultural sectors relationship with wind energy policy diffusion in the U.S. Furthermore, the current research design allows us to observe the behavioral change of the factors of wind energy policy diffusion under Republican and non-Republican state governance.

Our analysis could be expanded and improved in several ways. First, the current study is limited to only eight years of data. Future scholars may focus on a longer time frame in order to reveal the motivations behind early wind energy adopters in the region. These studies can be especially helpful in understanding the policy environment without the existence of economic or other political pressures.

Our next suggestion would be to include socio-demographic variables such as the education level of these states. A detailed analysis of the science scores of the focal states resulted that all seven states provide science education above U.S. average [89]. The variable could not be included in the current analysis as a result of the data availability. In addition, the West North Central region has the eighth lowest population density among nine Census divisions in 2015 [89] and even though the unemployment rate in the region has always been lower than the U.S. average, the region is known to have increasingly industrialized agriculture (fewer small and family owned farms) and out-migration from rural areas [62]. Inclusion of relevant socio-demographic factors may provide deeper insight into the importance of these factors for wind energy policy diffusion in the focal states.

We also suggest using a distributed (time-) lagged model in order to empirically investigate the role of neighboring on the diffusion of policies. Distributed lagged models are utilized to explain the current values of a dependent variable based on both the current and the previous (lagged) values of the same explanatory variable. Using specific types of policies (e.g., Renewable Portfolio Standards and net metering), a time-lagged model may improve the understanding of the diffusion process and related details (i.e., timing and progress of the diffusion process).

In the current study, we consider both time-varying and time-invariant factors. Future studies may consider using more advanced techniques (i.e. a generalized linear mixed effects regression analysis) that create a hierarchical structure for the different technical capacities and provide for a more comprehensive explanation of the diffusion of wind energy policy in the region.

A detailed analysis modelled after Dolowitz and Marsh (2000)'s policy diffusion framework would also extend the understanding of state's wind energy policy diffusion [10]. In particular, a systematic and comprehensive analysis of state-level policy diffusion will help in further investigation of the negative relationship between wind energy potential and the number of wind energy policies, as well as the behavioral difference of the agricultural factors under Republican and non-Republican state government controls in the focal states.

A second policy analysis model that we suggest future scholars to investigate is the political culture model of Daniel Elazar (1966) [90]. Elazar describes political culture as "attitudes, values, beliefs, and orientations that individuals in a society hold regarding their political system" and defines three political-culture types among Americans: (i) moral political culture, in which the society is held to be more important than the individual, (ii) individual political culture, in which the government is considered having a utilitarian orientation and is restricted from the areas which encourage private initiative, and (iii) traditional political culture, in which prominent social and family ties plays important role in governance of states. Elazar's political culture model is still considered important to define the differences in governances between states and may provide further explanation on the similarities and differences of the paths that states follow while implementing wind energy policy.

The result of the current empirical study appears to highlight the significance of state-level policies to enable and facilitate the development of wind energy in these states. These results further suggest that the economic potential of this industry is important to state and local governments and appears to be supported by Republican state governments. While this may seem ideologically inconsistent, these governments may see green wind energy as an important business sector, with substantive economic development potential for their state.

Appendix A. Summary statistics of states

IOWA	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	12.00	0.93	11.00	13.00
localpol	9.38	4.50	2.00	14.00
windpot (Gwh)	1723588.00	0.00	1723588.00	1723588.00
gsp($/capita)	47415.25	1696.43	45195.00	50086.00
unempl (%)	4.98	0.95	3.70	6.40
valofagr($/capita)	3803.43	735.26	2722.53	4765.61
estinagr (‰)	3.89	0.45	3.23	4.44
rstategov(dummy)	0.00	0.00	0.00	0.00

KANSAS	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	4.63	1.06	2.00	5.00
localpol	8.50	2.88	4.00	12.00
windpot (Gwh)	3101576.00	0.00	3101576.00	3101576.00
gsp($/capita)	45427.00	1001.40	43770.00	46890.00
unempl (%)	5.61	1.12	4.20	7.10
valofagr($/capita)	1947.95	319.76	1408.69	2326.29
estinagr (‰)	2.64	0.09	2.56	2.82
rstategov(dummy)	0.63	0.52	0.00	1.00

MINNESOTA	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	15.88	1.13	14.00	18.00
localpol	16.38	9.07	2.00	27.00
windpot (Gwh)	1428525.00	0.00	1428525.00	1428525.00
gsp($/capita)	51349.63	1466.40	48884.00	53380.00
unempl (%)	5.69	1.46	3.70	7.80
valofagr($/capita)	1476.97	229.80	1013.83	1751.76
estinagr (‰)	3.34	0.21	3.02	3.65
rstategov(dummy)	0.00	0.00	0.00	0.00

MISSOURI	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	7.50	1.60	6.00	10.00
localpol	5.13	2.47	1.00	8.00
windpot (Gwh)	689519.00	0.00	689519.00	689519.00
gsp($/capita)	42341.25	513.94	41598.00	43118.00
unempl (%)	7.30	1.65	5.00	9.60
valofagr($/capita)	701.48	90.56	557.20	802.87
estinagr (‰)	1.70	0.08	1.58	1.80
rstategov(dummy)	0.13	0.35	0.00	1.00

NEBRASKA	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	5.75	1.39	3.00	7.00
localpol	12.25	6.45	4.00	22.00
windpot (Gwh)	3011253.00	0.00	3011253.00	3011253.00
gsp($/capita)	50605.63	2032.48	47770.00	53099.00
unempl (%)	3.88	0.63	3.00	4.60
valofagr($/capita)	4159.68	822.40	2971.43	5301.19
estinagr (‰)	3.43	0.11	3.22	3.59
rstategov(dummy)	0.00	0.00	0.00	0.00

NORTH DAKOTA	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	5.38	0.92	4.00	6.00
localpol	5.88	5.36	0.00	13.00
windpot (Gwh)	2537825.00	0.00	2537825.00	2537825.00
gsp($/capita)	60075.63	9476.71	48379.00	71056.00
unempl (%)	3.25	0.51	2.70	4.10
valofagr($/capita)	5191.61	462.28	4497.81	5850.40
estinagr (‰)	5.17	0.43	4.47	5.83
rstategov(dummy)	1.00	0.00	1.00	1.00

SOUTH DAKOTA	**Mean**	**Std. Dev.**	**Min.**	**Max.**
statepol	6.50	1.93	3.00	8.00
localpol	7.75	3.54	2.00	12.00
windpot (Gwh)	2901858.00	0.00	2901858.00	2901858.00
gsp($/capita)	46608.25	986.56	45457.00	47972.00
unempl (%)	4.04	0.79	3.10	5.00
valofagr($/capita)	5537.79	945.71	4126.09	6808.50
estinagr (‰)	5.10	0.43	4.59	5.65
rstategov(dummy)	1.00	0.00	1.00	1.00

Appendix B. Summary statistics of variables

statepol	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	6.14	1.74	2	14
2009	7.14	1.60	4	15
2010	8.00	1.56	5	16
2011	8.43	1.53	5	16
2012	8.43	1.53	5	16
2013	8.86	1.53	5	16
2014	9.29	1.51	5	16
2015	9.57	1.73	5	18

localpol	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	2.14	1.46	0	4
2009	3.86	2.12	0	6
2010	6.86	3.39	1	11
2011	8.57	4.58	4	17
2012	11.29	5.19	7	22
2013	12.71	5.31	7	23
2014	13.71	5.44	7	23
2015	15.43	6.63	8	27

windpot (Gwh)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	2199163.43	929282.08	689519.00	3101576.00
2009	2199163.43	929282.08	689519.00	3101576.00
2010	2199163.43	929282.08	689519.00	3101576.00
2011	2199163.43	929282.08	689519.00	3101576.00
2012	2199163.43	929282.08	689519.00	3101576.00
2013	2199163.43	929282.08	689519.00	3101576.00
2014	2199163.43	929282.08	689519.00	3101576.00
2015	2199163.43	929282.08	689519.00	3101576.00

gsp($/capita)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	46925.71	2546.30	43118.00	51234.00
2009	46021.29	2651.89	42012.00	48884.00
2010	47119.71	3584.40	42204.00	52185.00
2011	48695.71	4964.84	41598.00	57066.00
2012	50344.86	8440.93	41926.00	68105.00
2013	50577.57	8230.32	42487.00	67651.00
2014	51657.00	9370.83	42442.00	71056.00
2015	51598.29	7810.59	42943.00	67305.00

unempl (%)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	4.27	1.17	3.10	6.10
2009	6.29	1.88	4.10	9.30
2010	6.21	1.98	3.80	9.60
2011	5.66	1.67	3.50	8.50
2012	4.97	1.29	3.10	7.00
2013	4.59	1.24	2.90	6.70
2014	4.09	1.14	2.70	6.20
2015	3.63	0.79	2.70	5.00

valofagr($/capita)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	3014.84	1727.70	722.42	5171.19
2009	2471.09	1531.64	557.20	4497.81
2010	2790.58	1750.10	567.59	5417.24
2011	3725.12	2228.32	732.94	6808.50
2012	3267.33	1877.14	712.97	5522.79
2013	3435.30	1973.17	742.94	5813.61
2014	3603.28	2069.25	772.91	6104.42
2015	3771.25	2165.38	802.87	6395.24

estinagr (‰)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	3.41	1.22	1.62	5.29
2009	3.52	1.38	1.58	5.83
2010	3.52	1.28	1.63	5.36
2011	3.48	1.19	1.70	5.14
2012	3.76	1.35	1.78	5.51
2013	3.85	1.35	1.80	5.65
2014	3.63	1.19	1.71	5.11
2015	3.71	1.26	1.76	5.58

rstategov (dummy)	**Mean**	**Std. Dev.**	**Min.**	**Max.**
2008	0.43	0.53	0	1
2009	0.29	0.49	0	1
2010	0.29	0.49	0	1
2011	0.43	0.53	0	1
2012	0.43	0.53	0	1
2013	0.43	0.53	0	1
2014	0.43	0.53	0	1
2015	0.43	0.53	0	1

Appendix C. State-level policies and incentives for wind energy [73]

IOWA

	Name	Category	Policy/Incentive type	Created	Last updated
1	Renewable Energy Equipment Exemption	Financial Incentive	Sales Tax Incentive	1/1/2000	2/10/2016
2	Special Assessment of Wind Energy Devices	Financial Incentive	Property Tax Incentive	1/1/2000	11/13/2015
3	Property Tax Exemption for Renewable Energy Systems	Financial Incentive	Property Tax Incentive	1/1/2000	2/10/2016
4	Alternate Energy Revolving Loan Program	Financial Incentive	Loan Program	1/1/2000	2/5/2016
5	Alternative Energy Law	Regulatory Policy	Renewables Portfolio Standard	1/1/2000	12/9/2016
6	Net Metering	Regulatory Policy	Net Metering	1/1/2000	6/18/2015
7	Mandatory Utility Green Power Option	Regulatory Policy	Mandatory Utility Green Power Option	9/24/2001	1/29/2016
8	Interconnection Standards	Regulatory Policy	Interconnection	6/18/2003	9/30/2015
9	Energy Replacement Generation Tax Exemption	Financial Incentive	Corporate Tax Exemption	7/10/2003	1/29/2016
10	Renewable Energy Production Tax Credits (Corporate)	Financial Incentive	Corporate Tax Credit	6/23/2005	12/9/2016
11	Renewable Energy Production Tax Credit (Personal)	Financial Incentive	Personal Tax Credit	6/27/2005	12/9/2016
12	Small Wind Innovation Zone Program	Regulatory Policy	Wind Permitting Standards	6/7/2011	1/29/2016

13	Iowa Area Development Group Energy Bank Revolving Loan Program	Financial Incentive	Loan Program	4/26/2013	2/10/2016

KANSAS

	Name	**Category**	**Policy/Incentive type**	**Created**	**Last updated**
1	Renewable Energy Property Tax Exemption	Financial Incentive	Property Tax Incentive	1/1/2000	6/8/2015
2	Green Building Requirement for New Municipal Buildings	Regulatory Policy	Energy Standards for Public Buildings	1/31/2008	12/18/2015
3	Renewable Energy Goal	Regulatory Policy	Renewables Portfolio Standard	5/27/2009	6/8/2015
4	Net Metering	Regulatory Policy	Net Metering	5/29/2009	8/12/2015
5	Interconnection Guidelines	Regulatory Policy	Interconnection	6/8/2009	8/12/2015

MINNESOTA

	Name	**Category**	**Policy/Incentive type**	**Created**	**Last updated**
1	Wind and Solar-Electric (PV) Systems Exemption	Financial Incentive	Property Tax Incentive	1/1/2000	3/26/2015
2	Agricultural Improvement Loan Program	Financial Incentive	Loan Program	1/1/2000	3/11/2015
3	Value-Added Stock Loan Participation Program	Financial Incentive	Loan Program	1/1/2000	2/13/2015
4	Renewable Energy Production Incentive	Financial Incentive	Performance-Based Incentive	1/1/2000	1/7/2015
5	Net Metering	Regulatory Policy	Net Metering	1/1/2000	11/23/2015

6	Solar and Wind Easements & Local Option Rights Laws	Regulatory Policy	Solar/Wind Access Policy	1/1/2000	5/15/2015
7	Comprehensive Energy Savings Plan for State Facilities	Regulatory Policy	Energy Standards for Public Buildings	1/1/2000	2/24/2015
8	Wind Energy Sales Tax Exemption	Financial Incentive	Sales Tax Incentive	11/29/2001	12/9/2015
9	Renewable Development Fund	Regulatory Policy	Public Benefits Fund	12/3/2001	2/13/2015
10	Interconnection Standards	Regulatory Policy	Interconnection	6/19/2003	1/21/2016
11	Xcel Energy - Renewable Development Fund Grants	Financial Incentive	Grant Program	1/12/2004	3/5/2015
12	Minnesota Power - Power Grant Program	Financial Incentive	Grant Program	5/26/2006	1/12/2016
13	Renewable Energy Standard	Regulatory Policy	Renewables Portfolio Standard	3/5/2007	11/19/2015
14	Community-Based Energy Development Tariff	Regulatory Policy	Other Policy	6/6/2007	12/9/2015
15	Farm Opportunities Loan Program	Financial Incentive	Loan Program	5/26/2009	3/14/2017
16	Fix-Up Loan	Financial Incentive	Loan Program	10/1/2010	6/1/2016
17	Rural Minnesota Energy Board Property Assessed Clean Energy (PACE) Program	Financial Incentive	PACE Financing	5/1/2015	5/1/2015
18	PACE Program	Financial Incentive	PACE Financing	5/4/2015	5/4/2015
19	Wind Energy Conversion Systems	Regulatory Policy	Solar/Wind Access Policy	10/11/2016	10/11/2016

MISSOURI

	Name	Category	Policy/Incentive type	Created	Last updated
1	Energy Loan Program	Financial Incentive	Loan Program	1/1/2000	9/4/2015
2	Interconnection Guidelines	Regulatory Policy	Interconnection	6/18/2003	1/11/2016
3	Renewable Portfolio Standard	Regulatory Policy	Renewables Portfolio Standard	11/4/2004	6/24/2016
4	Net Metering	Regulatory Policy	Net Metering	6/27/2007	4/14/2015
5	Renewable Energy Standard	Regulatory Policy	Renewables Portfolio Standard	6/27/2007	5/18/2015
6	Energy Standards for Public Buildings	Regulatory Policy	Energy Standards for Public Buildings	7/23/2008	3/17/2016
7	Clean Energy Development Boards	Financial Incentive	PACE Financing	7/12/2010	5/5/2016
8	Missouri Clean Energy District	Financial Incentive	PACE Financing	8/27/2014	3/17/2016
9	Set the PACE	Financial Incentive	PACE Financing	8/27/2014	1/12/2016
10	Green Building Policy for Municipal Buildings	Regulatory Policy	Energy Standards for Public Buildings	11/3/2014	3/17/2016
11	Show Me PACE	Financial Incentive	PACE Financing	5/5/2016	5/5/2016

NEBRASKA

	Name	**Category**	**Policy/Incentive type**	**Created**	**Last updated**
1	Dollar and Energy Savings Loans	Financial Incentive	Loan Program	1/1/2000	10/5/2015
2	Solar and Wind Easements	Regulatory Policy	Solar/Wind Access Policy	1/1/2000	10/5/2015
3	Sales and Use Tax Exemption for Community Renewable Energy Projects	Financial Incentive	Sales Tax Incentive	5/31/2007	8/24/2015
4	Net Metering	Regulatory Policy	Net Metering	5/19/2009	6/23/2015
5	Interconnection Guidelines	Regulatory Policy	Interconnection	5/19/2009	10/5/2015
6	Property Tax Exemption for Renewable Energy Generation Facilities	Financial Incentive	Property Tax Incentive	8/3/2011	6/16/2015
7	Sales and Use Tax Exemption for Renewable Energy Property	Financial Incentive	Sales Tax Incentive	7/12/2013	8/26/2015
8	Property-Assessed Clean Energy Financing	Financial Incentive	PACE Financing	4/1/2016	4/26/2016
9	Wind Energy Conservation System Requirements	Regulatory Policy	Solar/Wind Permitting Standards	11/15/2016	11/15/2016

NORTH DAKOTA

	Name	**Category**	**Policy/Incentive type**	**Created**	**Last updated**
1	Renewable Energy Tax Credit	Financial Incentive	Corporate Tax Credit	1/1/2000	3/21/2017
2	Renewable Energy Property Tax Exemption	Financial Incentive	Property Tax Incentive	1/1/2000	10/28/2016

3	Net Metering	Regulatory Policy	Net Metering	1/1/2000	5/10/2016
4	Renewable and Recycled Energy Objective	Regulatory Policy	Renewables Portfolio Standard	8/24/2007	10/28/2016
5	Wind Easements	Regulatory Policy	Solar/Wind Access Policy	2/16/2010	5/10/2016
6	Sales and Use Tax Exemption for Electrical Generating Facilities	Financial Incentive	Sales Tax Incentive	9/1/2011	10/28/2016

SOUTH DAKOTA

	Name	**Category**	**Policy/Incentive type**	**Created**	**Last updated**
1	Large Commercial Wind Exemption and Alternative Taxes	Financial Incentive	Property Tax Incentive	3/6/2008	5/13/2015
2	Renewable, Recycled and Conserved Energy Objective	Regulatory Policy	Renewables Portfolio Standard	3/21/2008	10/28/2016
3	High-Performance Building Requirements for State Buildings	Regulatory Policy	Energy Standards for Public Buildings	7/18/2008	10/28/2016
4	Interconnection Standards	Regulatory Policy	Interconnection	6/15/2009	10/27/2016
5	Model Ordinance for Siting of Wind-Energy Systems	Regulatory Policy	Solar/Wind Permitting Standards	1/27/2010	10/28/2016
6	Wind Easements	Regulatory Policy	Solar/Wind Access Policy	2/15/2010	10/28/2016
7	Renewable Energy System Exemption	Financial Incentive	Property Tax Incentive	4/7/2010	4/28/2015
8	Renewable Energy Facility Sales and Use Tax Reimbursement	Financial Incentive	Sales Tax Incentive	6/26/2013	10/31/2016

Appendix D. Cities and counties with wind energy ordinances [74]

IOWA

	City/County name	Year	Content[i]
1	Marshall County, IA	1997	S
2	Mason City, IA	2006	S/M
3	Polk County, IA	2009	S/L
4	Boone County, IA	2010	S/L
5	Delaware County, IA	2010	S/L
6	Dickinson County, IA	2010	S
7	O'Brien County, IA	2010	L
8	Plymouth County, IA	2010	S/L
9	Tama County, IA	2010	S/L
10	Greene County, IA	2011	S/L
11	Poweshiek County, IA	2011	S/L
12	Story County, IA	2013	S/L
13	Cherokee County, IA	2014	S/L
14	Floyd County, IA	2015	S/L
15	Muscatine County, IA	2016	L
16	Palo Alto County, IA	2016	S/L
17	Guthrie Center, IA	n/a	S/L

KANSAS

	City/County name	Year	Content
1	Sedgwick, KS	1989	S/L
2	Lyon County, KS	2008	L
3	Pottawattamie County, KS	2008	L
4	Saline County, KS	2008	S/L
5	Hays, KS	2009	U
6	Pawnee County, KS	2009	L
7	Osage County, KS	2010	L
8	Marion County, KS	2012	L

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[i] The content of the ordinances includes small (S), midsize (M), large (L), mounted (MO), micro (MI) (midsize and unspecified (U) size wind energy projects.

9	Pratt County, KS	2012	L
10	Sumner County, KS	2012	L
11	Barton County, KS	2013	S/L
12	Merriam, KS	2015	S
13	Harper County, KS	2016	L
14	Kingman, KS	2016	S
15	Miami County, KS	2016	L
16	Topeka, KS	n/a	S/L

MINNESOTA

	City/County name	**Year**	**Content**
1	Chippewa County, MN	2005	S/L
2	Minneapolis, MN	2007	S/MO
3	Brainerd, MN	2009	S/L
4	Clay County, MN	2009	S/L
5	Mower County, MN	2009	S/L
6	Rockville, MN	2009	S/L
7	Murray County, MN	2010	S/L
8	Norman County, MN	2010	S/L
9	Stevens County, MN	2010	S
10	Wabasha, MN	2010	S/L
11	Watertown, MN	2010	S/MO
12	Clearwater County, MN	2011	S/L
13	Fairmont, MN	2011	U
14	Lyon County, MN	2011	S/L
15	Maplewood, MN	2011	S
16	Otter Tail County, MN	2011	S/L
17	Renville County, MN	2011	S/L
18	City of Mahtomedi, MN	2012	S
19	Fillmore County, MN	2012	S/L
20	Hibbing, MN	2012	S/L
21	Otsego County, MN	2012	S
22	Washington County, MN	2012	S
23	Plymouth, MN	2013	S
24	Freeborn County, MN	2015	S/L

25	Goodhue County, MN	2015	S/L
26	Martin County, MN	2015	S/L
27	Orono, MN	2015	S
28	Cottonwood County, MN	2016	S/L
29	Pipestone County, MN	2016	S/L
30	Wright County, MN	2016	S/L

MISSOURI

	City/County name	**Year**	**Content**
1	Palmyra, MO	2007	S,L
2	Blue Springs, MO	2009	S
3	Gladstone, MO	2009	S
4	Raymore, MO	2010	S,L
5	Clayton, MO	2012	S
6	Columbia, MO	2012	S,L
7	O'Fallon, MO	2012	S
8	Clay County, MO	2015	S,L
9	Kansas City, MO	2016	S
10	Warrensburg, MO	2016	S,L

NEBRASKA

	City/County name	**Year**	**Content**
1	Cedar County	2000	S, L
2	Madison	2003	S, L
3	Dakota County	2006	S
4	Gretna	2008	S, L
5	Saunders County	2009	S, M
6	Gothenburg	2010	S
7	Grand Island	2010	MI, S, L
8	Nance County	2010	S, L
9	Saline County	2010	S, L
10	Lancaster County	2011	L
11	Cherry County	2012	S, L
12	Lincoln County	2012	S, L
13	Red Willow County	2012	S, L

14	Fillmore County	2013	S, L
15	Polk County	2013	S, L
16	Thayer County	2013	S, L
17	Custer County, NE	2014	S, L
18	Holt County	2014	S, L
19	Keith County	2014	S, L
20	Frontier County	2015	S, L
21	Nebraska City	2015	S, L
22	Scottsbluff	2015	S
23	Cass County	2016	S, L
24	Colfax County	2016	S, L
25	Gage County	2016	S, L
26	Knox County	2016	S, L
27	La Vista	2016	S
28	Imperial	n/a	S, L
29	Sarpy County	n/a	S

NORTH DAKOTA

	City/County name	**Year**	**Content**
1	Hebron	2010	S
2	Apple Creek Township	2011	S
3	Burleigh County	2011	S, M, L
4	Valley City	2011	S
5	Bowman County	2012	L
6	Golden Valley County	2012	L
7	Stark County	2012	L
8	Bismarck	2013	S
9	McLean County	2013	L
10	Morton County	2013	M, L
11	Stutsman	2013	L
12	Grant County	2015	L
13	Williams County	2015	L
14	McKenzie County	2016	L
15	Divide County	2017	L
16	Fargo	2017	S

SOUTH DAKOTA

	City/County name	Year	Content
1	Brookings	2001	L
2	Deuel County	2008	S, L
3	Aberdeen	2009	S, L
4	Union County	2009	S
5	Brown County	2010	S, L
6	Clay County	2010	S, L
7	Lawrence	2010	S, L
8	Madison	2012	S
9	Pennington County	2012	S, L
10	Lake County	2014	S, L
11	Minnehaha County	2014	S, L
12	Moody County	2014	S
13	Watertown	2017	S, L

Appendix E. Assumptions of the random-effects panel data analysis

Assumption [84]	**Definition**	**Test method**	**Stata code**	**Results**
No perfect collinearity	All explanatory variables change over time and there is no perfect linear relationship among them.	Variance inflation factors are used to test for the bias estimates [91].	The Stata command to test the model for multicollinearity is *vif*.	No perfect linear relationships among the explanatory variables was found: The computed variance inflation factor values varied between 1.87 and 5.15. Further investigation would be needed if the computed variance inflation factor values were greater than 10 (or tolerances – 1/vif – were lower than 0.10) [91].
Strict exogeneity	Explanatory variables of the model are uncorrelated with the idiosyncratic errors, u_{it}, for each time period.	Davidson MacKinnon test is used to examine the exogeneity of explanatory variables, one at a time. The test procedure compares the results of the original model with an upgraded model including additional (instrumental) variables that are in potential relationship with the existing explanatory variables of the original model [92].	The Stata command to create the additional instrumental variable is *xtivreg* and the command to compare the results of the two models is *dmexogxt*.	The null hypothesis of exogeneity was satisfied for all main explanatory variables.

Homoskedasticity	The variance of the idiosyncratic error, u_{it}, remains the same identical for all values of the dependent variable: $Var\ (u_{it}\|X_i a_i) = Var\ (u_{it}) = \sigma_u^2, for\ all\ t = 1, \dots, T$	White test is used to detect heteroscadasticity. White test is a generalized case of Breusch Pagan test to detect both linear and nonlinear forms of heteroscadasticity [93].	The Stata command for the White test is *imtest, white.*	The null hypothesis of homoskedasticity was failed to be rejected for both models.
No serial correlation	Conditional on all explanatory variables and unobserved heterogeneities, a_i, the idiosyncratic errors, u_{it}, are uncorrelated over time: $Cov\ (u_{it}, u_{is}\|X_i, a_i) = 0$	Woolridge's test for serial correlation is used to identify the correlation among the idiosyncratic errors, u_{it}, over time [84].	The Stata command to test serial correlation is *xtserial*.	The null hypothesis of no serial correlation among the idiosyncratic errors, u_{it}, was rejected for both models, therefore the current study corrects the model for serial correlation.
Normality	The idiosyncratic error, u_{it}, is independent and identically distributed as N (0, σ_u^2) for each t.	An extension of Jarque-Bera normality test is proposed by Alejo et al (2015) to explore skewness and excess kurtosis of the idiosyncratic error, u_{it} [94].	The Stata command to test the idiosyncratic error, u_{it}, for normality is *xtsktest*.	No statistically significant skewness and excess kurtosis were detected for the idiosyncratic error, u_{it}, in both models.
Model specification: $y_{it} = \beta_1 x_{it1} + \cdots + \beta_k x_{itk} + a_i + u_{it}, i = 1, \dots, 7\ and\ t = 1, \dots, 8$, where β_j are the parameters to estimate, a_i is the unobserved heterogeneity, and u_{it} is the idiosyncratic error.				

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CHAPTER FIVE

CONCLUSION

In this dissertation, we provided an outlook on the current state of knowledge on the diverging paths of renewable energy for countries and empirically investigated the factors of wind energy deployment and policy in the United States (U.S.).

Chapter Two contributed to the existing literature on renewable energy by providing a systematic review for the factors of renewable energy deployment of countries. The review included 60 studies, which, in total, considered 489 factors. These factors were classified into seven main categories (economic, environmental, political, regulatory, social, technical potential, and technological) and 239 subcategories. The categories and subcategories were, then, classified as either: (i) drivers, (ii) barriers, or (iii) undetermined. Out of seven main categories that we defined in Chapter Two, economic, environmental and social factors were the only ones that were considered drivers. The impacts of political, regulatory, technical potential and technological factors were considered undetermined. Only one subcategory, national income, was found to be a driver. All remaining subcategories were found to have undetermined impacts due to: (i) the small number of manuscripts considering these factors either as drivers or barriers, and/or (ii) the lack of statistically significant positive or negative impacts on the renewable energy deployment of countries. None of the main categories or subcategories were found to be a barrier.

In Chapter Three, we suggested further investigation of three important deficiencies that the current literature on the renewable energy deployment presents. The first deficiency was the over – and underrepresentation of several areas including the factors considered, countries represented, and periods analyzed by the manuscripts. We suggested equal representation of these areas in the future studies. The second deficiency that we noted was the inconsistent definition of renewable energy deployment, the dependent variable, within the manuscripts. Our suggestion was the use a consistent definition of renewable energy deployment in future studies. The last deficiency that we noted in the current renewable energy deployment literature was the variation of the types of renewable energy sources considered among the manuscripts. We suggested future scholars clearly describe the input that they include in their studies.

Chapter Three focused on the most promising renewable energy source (wind) in the market [1] and empirically investigated the significance of a number of economic and environmental factors of the deployment of U.S. wind energy using data from 39 states over a 16-year period (2000-2015). Economic factors included gross state product, the value of agricultural sector, and the unemployment rate. All economic factors were found to be significantly and positively related to the deployment of wind energy in the U.S. Environmental factors included carbon dioxide (CO_2) emissions, nitrogen oxide (NO_X) emissions, and water use. CO_2 and NO_X emissions were found to be significant and negatively associated to the U.S. wind energy deployment. This study adds to the literature by including previously neglected factors, such as the contribution of the agricultural sector to the national economy and NO_X emissions to understand the deployment of U.S. wind energy.

Our suggestions for further investigation of the U.S. wind energy deployment included: (i) the use of other factors, such as social and political factors; (ii) the inclusion of interaction variables (i.e., the interaction between the economic and environmental factors); and (iii) the consideration of other statistical methods (i.e., a generalized linear mixed model).

Chapter Four focused on the factor of wind energy policy diffusion. The existing literature suggested that the diffusion of state- and local-level wind policies are positively associated to the deployment of wind energy. We designed our empirical analysis after Berry and Berry's internal and external factors of policy diffusion model (1996) and focused on seven neighboring Midwestern states, which are located in the middle of the U.S. Wind Energy Corridor, to control for the external factors. The list of internal factors that were considered in the random-effects panel data regression analysis from 2008 to 2015 included wind power potential, per capita gross state product, unemployment rate, per capita value of the agriculture sector, number of the establishments in agricultural sector and state government control. Through the addition of interaction terms, we also explored the behavioral differences in these regressors under Republican and non-Republican state governance. The interaction between the value of the agricultural sector and Republican state government as well as the interaction between the number of the establishments in the agricultural sector and Republican state control, were found to be statistically related to states' wind energy policy diffusion from 2008 to 2015. In addition, wind energy potential, per capita gross state product, the unemployment rate, and the number of establishments in the agricultural sector were found to be statistically significant factors of state-level wind energy policy diffusion. At the local level, economic variables, including gross state product per capita and unemployment rate, were the only factors significantly related to wind energy policy diffusion.

We suggested that the analysis of wind energy policy diffusion in the U.S. could be expanded and improved in several ways through: (i) the use of a longer time period and other factors, such as socio-demographic ones; (ii) consideration of other statistical methods (i.e., a distributed lagged model or a generalized linear mixed model); and (iii) consideration of other political analysis methods (i.e., policy diffusion framework and political culture model).

Overall, this dissertation provided an outlook on the existing renewable energy deployment literature and empirically identifies the factors of wind energy generation capacity and wind energy policy diffusion in the U.S. This dissertation added to the existing literature in several ways. First, this dissertation provided a systematic picture of the current state of knowledge on the factors of renewable energy deployment of countries. Second, the significance of previously neglected factors of renewable energy and wind energy deployment (i.e. NO_X emissions, water use, and agricultural sector presence) were considered by two empirical studies in this dissertation. Third, this dissertation investigated the significance of state government control along with economic, agricultural sector specific and technical factors on the diffusion of wind energy policy at both state and local level. Finally, this dissertation provided a reproducible structure of the methodology and detailed definition of the data sources to allow future researchers to update these studies and integrate new findings to the literature.

We suggest that the findings of this dissertation can be extended in two important ways. First, the significance of the factors that this dissertation considers, including economic, environmental, technical, agricultural sector specific and political factors, can be further investigated for other countries. Future scholars can compare the findings of these investigations with the findings from the studies in this dissertation, and may lead to a further understanding of these factors' global significances.

We also suggest that social and moral elements are important factors of renewable, and in particular wind, energy deployment because these elements contribute to the social acceptance of renewable energy sources. The wind energy deployment literature highlights social acceptance but the number of studies that incorporates cultural and moral elements remains limited. Similarly, there is no study in the current wind energy policy diffusion literature that considers the contribution of cultural and moral motives to the increased levels of legislative support to wind energy. In addition to the factors considered in this dissertation, the inclusion of cultural and moral elements in future research will help in further understanding the difference in wind energy or wind energy policy deployment of states/countries.

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