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Article

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Evaluation of the Role of Renewables Consumption on Economic Growth of the U.S. Regions

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ABSTRACT

The article is devoted to a modern situation in the U.S. electricity analysis per state, where renewable energy consumption has grown drastically since the early 2000s. The article estimates electricity restructuring results and their influence on the modern state of this branch of industry. We attempted to assess the influence of various factors involved in the economic growth of the U.S. per state using the methods of cluster and panel data analysis. The numerical data collected refer to the period of 2000-2014. We prove the significance of the renewables share in the economic growth of particular states and the U.S. as a nation.

Keywords: Renewables, Electricity Restructuring, Economic Growth
JEL Classifications: O18, O51

1. INTRODUCTION

The electric industry is playing an important role in any economy. The electricity price determines the growth of the economy in general and its entities in particular. Moreover, the energy production should influence the positive dynamics of different fundamental facets of any country, its welfare and its steady development. These basic expectations and demands are met by the authorities that try to decrease or optimize the level of energy rates. This facilitates the development of the economy in general and sets up requirements to reduce emissions related to the use of fossil fuels. The former can be achieved by using cheaper primary resources and making the energy production or distribution more competitive, whereas, the latter is connected with the reforms in the U.S. electric industry, which is not applied in all the states, yet. The reforms were implemented in the late 1990s-early 2000s. The early 2000s showed a nationwide spread of generating supplies working on renewable energy sources. The transformation was boosted after the downturn of 2008 with federal incentives for developing renewable energy resources.

Numerous reports have been published on the role of using renewables for economic growth in different countries. This popular topic is raised at international conferences, with international and national organizations providing monthly reviews and statistics. The influence of the growing consumption of renewable energy for economic growth is taking into consideration different countries and regions in Apergis and Danuletiu, 2014; Inglesi-Lotz, 2013; 2016; Arouri, et al., 2014; Menegaki and Ozturk, 2016; Ben Jebli et al., 2016; Bhattacharya et al., 2016; Rafindadi and Ozturk, 2017. An analysis of 80 countries of Western Europe, Asia, Africa and Latin America showed a clear interaction between the renewable energy consumption and the economic growth of the countries (Apergis and Danuletiu, 2014). A work on developing renewables of different countries in Africa showed the importance of the process everywhere even though the countries differed sufficiently (Arouri et al., 2014). Another research on renewables on the countries of Organization for Economic Co-operation and Development showed that the most important factors influencing gross domestic product (GDP) include the share of renewables in gross energy consumption, the number of employees and the volume of the capital invested, including investments into innovative solutions (Inglesi-Lotz, 2016). The influence is usually estimated using the dynamic panel data method.

A large a number of works are devoted to the current stage and development of the U.S. electric industry. The issues of stimulating the economic growth are being topical. Therefore, the society is concerned about additional employment opportunities, stable electricity rates, economic growth of each state, and environmental constraints. Borenstein and Bushnell (2015) considered the history of renewable energy resources development and the current trends and linked the current electricity industry state with the social demands to protect the environment. They further analyzed causes and effects of restructuring processes in the electricity industry in the U.S. states since the mid-1990s. Along with the benefits gained, the authors mention some disadvantages and failed expectations. It is significant to regulate interactions between the market players. More than half of the states recently regulate the process of setting up renewable energy power supplies. However, Bushnell et al. (2015) highlights that it is the regulation which the industry adopted by a state plays a great role in reducing air emissions.

This analysis focuses on the influence of renewable energy consumption on the economic growth of the U.S. The country is considered as a federation of 51 states. In addition, the analysis takes into account the peculiarities of the energy industry in each state and uses indicators that reflect the energy policy objectives.

2. THE ELECTRIC INDUSTRY RESTRUCTURE IN U.S.

The mid-1990s was the period of restructuring in the U.S. electric industry, but not all the states took a part in the process. The activities that took place are briefly described in Table 1. The total number of the states that underwent restructuring is 23, with 7 states refusing further deregulation and 2 refusing the retail market liberation (retail choice) for various reasons.

The electric power industry restructuring may involve different processes, two of them are deregulation and retail choice. Deregulation means reducing regulation on the part of the government in a particular industry. While restructuring the utilities that generate energy from particular resources are singled out from the totality of vertically integrated companies. Deregulation refers mainly to the electric generation companies that do not have to be regulated in terms of their operations and rates due to the high level of competition. Retail choice means freedom of choosing a retailer for all the consumers.

Restructuring transforms were quite unsteady as the state authorities controlled the situation and corrected the actions depending on the local needs and demands. Bills on regulating the industry were enacted during 1995-2000. The previous monopolistic structure did not encourage optimization or reduction of production costs (Volkov and Preobrazhenskaja, 2005). Restructuring legislation took into account various aspects including, the schedule for wholesale and retail markets, the percentage, and consumers who could choose the utility company, the rules of selling the assets of generating companies, key points for electricity rates, and necessity of consumer education programs, etc. The initial time limits to introduce competition proved too optimistic in all the states and were corrected later. Consequently, some states faced a lack of competition, which allowed price manipulations and caused disagreements when changing the owner or introducing a new player on the market. As a result, that led to a halt in restructuring in some of the states and changes for markets in others.

California experienced the most negative consequences leading to the energy crisis of 2000. Analysts partly blamed the reforms as well as some external factors (Tukenov, 2005) such as a sharp increase in demand for electricity, restrictions to create new facilities, uncoordinated actions while introducing free prices on the wholesale and retail market. Besides, speculative operations on a part of some market players with the lack of control over large manufacturers are considered to be one of the external factors. State authorities often look at the California's experience when developing competitive relations or adopting their plans or programs.

The most positive example of a developed market in the U.S. electric industry is the PJM market, "one of the biggest deregulated markets in the world" (Tukenov, 2005). As early as 1927, three utilities, realizing the benefits and efficiencies possible by interconnecting to share their generating resources, formed the world's first continuing power pool[1]. The pool, at first, included companies from Pennsylvania, New Jersey, and Maryland. By 1997, the tipping point of market restructuring in the industry, the pool had been joined by companies from Ohio, Virginia, and Delaware. Yet, it covers 14 states of the U.S. The program of restructuring is considered successful. The market is deregulated and has a complicated management structure, effective technologies, and organized information flows.

At the beginning of restructuring, in the mid-1990s, a number of states introduced their programs paying attention to developing renewable energy. Researchers assumed that implemented market restructuring actively, the increase in the share of renewable energy might be the most intensive, and at the moment the effect with respect to their economic growth, in general, is the highest (Borenstein and Bushnell, 2015).

3. DEVELOPMENT OF RENEWABLE ENERGY

The U.S. electric power industry is developing at a high rate. The general electric utility capacity exceeded 1 bln kW in 2007 (Vihrev, 2008). The generating capacities introduced are various. In the early 2000s steam turbine power plants and combined cycle gas turbine plants dominated with a high number of coal-steam plants and almost no new hydro- or atomic power plants (Ibid). After the year of 2000, renewable energy markets began to develop actively with the highest number of new generation capacities with a leading driver of wind (Figure 1).

1 PJM history, http://pjm.com/about-pjm/who-we-are/pjm-history.aspx [Last accessed 2017 Jan 11].

Table 1: Electricity restructuring per state

State	Deregulation	Retail choice	Brief characteristic
Arkansas	Suspended	No	1997 – Arkansas PSC agreed to Entergy's restructuring plan. Preparations. Senate bill passed and signed in 1999. 2000 – Report on no market power. 2003 – The Arkansas General Assembly passed Act to continue regulating electric utility rates, deregulation suspended
Arizona	Suspended	No	1998 – House bill on deregulation was enacted and affirmed authorities to require utilities to open territories to retail competition. Since 1999 large companies were involved in a judicial proceeding over market access and asset rights. 2004 – Restructuring was placed on hold
California	Suspended	Suspended	1994 – Preparations. Prices for electric power the highest in the U.S. 1996 – Assembly Bill was enacted to restructure the California electric utility industry and implement retail direct access; an independent system operator and a power exchange were created to operate the power market. High competition in the wholesale and retail market. 2000-2001 – Energy crisis
Connecticut	Yes	Yes	1998 – House bill on electric restructuring was signed into law. Plans to create a competitive market in 2001 and sell non-nuclear generating assets in 2004. Weak activity on the market. 2009 – Residential and business customers had chosen an electric supplier
District of Columbia	Yes	Yes	2000 – Order issued on providing the implementation plan for retail choice; competitiveness in the retail market. 2001 – Sale of assets to the customers; the commission determines "price to compare;" consumer protection measures; customers' bills increase
Delaware	Yes	Yes	1999 – House bill on electric utility restructuring was enacted; plans to introduce competition into the retail segment and lower prices. 2006 – House bill on developing electric distribution companies was enacted, customers had to opt out of the deferral plan
Illinois	Yes	Yes	1996 – Pilot programs were introduced. 1997 – House bill on Electric Service Customer Choice and Rate Relief Act was enacted. 2009 – 97% of customers with a demand of over one megawatt and 75% of all the commercial customers are taking service from an alternative supplier
Massachusetts	Yes	Yes	1996 – Pilot programs were introduced. 1997 – House bill was enacted to restructure the electric power industry; sale of generating assets including nuclear plants. 2000 – Most customers receive power from their incumbent utility
Maryland	Yes	Yes	1997 – Task force on electric industry restructuring was created. 1999 – Plan to bring retail choice, new business ventures created aimed at a reduction in prices and development of new technologies in the industry. 2002 – Low competition with only 2.6% customers involved. Consider revising the electric choice program
Maine	Yes	Yes	1997 – The law was adopted to allow retail competition in 2000 requiring 30% of generation to be from renewable energy sources (including hydroelectric). Independent system operator was created. 2008 – New standards offering energy prices
Michigan	Yes	Yes	1998 – Phase-in schedule was adopted to gradually allow retail competition by 2002. 2002 – 22 licensed alternative electric suppliers. 2006 – Decline in the competition
Montana	Suspended	No	1997 – Senate bill on the electric utility industry restructuring and Customer Choice Act were enacted allowing large industrial consumers retail access by 1998 and all consumers by 2002. No conditions for a competitive market. 2003 – State refused to restructure the industry
New Hampshire	Yes	Yes	1996 – House bill was enacted requiring the PUC to implement a retail choice for all customers by 1998. 2001 – House bill was enacted and extended the period of restructuring
New Jersey	Yes	Yes	1997 – Order is issued to release a plan creating a retail choice that would give all residents and businesses the option of choosing their electricity supplier by 2001. Reduction in prices by 2001. 2002 – Task force made recommendations to apply strong consumer protections and mitigate further accumulation of deferred balance
New Mexico	Suspended	No	1997 – Restructuring plan submitted. The program was scheduled to begin in 1998. 1999 – The Electric Utility Restructuring Act, senate bill, was enacted, all consumers were scheduled to have retail access by 2002. A decision to authorize the state's IOUs to unbundle their operations delayed; 2003 – Senate bill repealed the Electric Utility Industry Restructuring Act of 1999

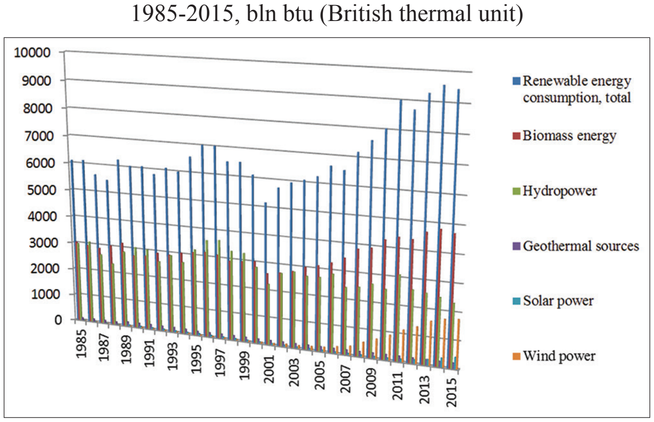
(Contd...)

Table 1: (*Continued...*)

State	Deregulation	Retail choice	Brief characteristic
Nevada	Suspended	No	1997 – Restructuring legislation, assembly bill, was enacted, to establish a market for customers to have access to potentially competitive electric services from alternative suppliers by the end of 1999. 2001 – Halt to electric utility deregulation due to high demand, low supply, and unstable prices
New York	Yes	Yes	1996 – Plan to have a competitive wholesale market by 1997, and a competitive retail market by early 1998 adopted; changes in the retail market till 2008; retail marketers' prices increased
Ohio	Yes	Yes	1996 – 2-year pilot program adopted. 1999 – Restructuring legislation, Senate bill, was signed into law, retail customers could choose their energy suppliers beginning January 1, 2001. The law required 5% residential rate reductions and a rate freeze for 5 years, requirement for consumer education programs. 2008 – Regulatory structure for electric public utility companies is significantly revised and new policies for the development of advanced and renewable energy are put forward
Oregon	Yes	Yes	1997 – Pilot program approved; 2001 – Legislation, house bill, was enacted to delay the date for implementing retail access for large customers, plans for restructuring were delayed
Pennsylvania	Yes	Yes	1996 – House Bill, the Electricity Generation Customer Choice, and Competition Act were enacted. 1999 – Retail access was made available to two-thirds of the state's customers. The main issue being the electricity costs, they decreased by 2003 and slightly increased later. 2010 – Expectations of deregulation lowering the rates failed
Rhode Island	Yes	Yes	1996 – Utility Restructuring Act, house bill, allowed the retail choice to be phased-in, residential consumers were scheduled to have retail access by July 1998. The most customers left the competitive market
Texas	Yes	Yes	1995 – Senate bill enacted to restructure the Texas' wholesale electric industry, an independent operator established. 2009 – Senate bill and house bill were introduced to halt electricity deregulation. Under the bills, a pilot program would first need to prove that electricity deregulation would lower rates. 2010 – Nodal wholesale market structure is proposed
Virginia	Suspended	Suspended	1998, 1999 – Restructuring legislation was signed; creation of an independent system operator, power exchange, and plans for pilot programs. Poor quality of service, electricity companies need to be controlled. 2007 – Return to the regulated electric power market

Source: Status of Electricity Restructuring per State, http://www.eia.gov/electricity/policies/restructuring/restructure_elect.html [Last accessed on 2017 Jan 15]

Figure 1: Renewable energy consumption estimates by source in U.S., 1985-2015, bln btu (British thermal unit)



Source: December 2016 monthly energy review, U.S. energy information administration, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf [Last accessed on 2017 Jan 12].

Although renewable energy capacities started to appear in the U.S. in the early 1960s, they got a new impulse and were diversified in the 2000s, boosted by the federal and state legislation.

Since 2005-2007, the consumption of energy generated by the wind and solar power facilities has been growing significantly. For instance, the wind generation share exceeded 10% in 11 states in 2015[2], with the leading states Iowa, South Dakota, and Kansas possessing more than 20% compared to the 2015 average for the U.S. in a total of 4.4%[3].

Development of renewable energy resources is a key point in developing the U.S. national economy. Energy production weighs quite a lot in the prices of final output and has a significant impact on the economy in terms of revenue and retail prices. Furthermore, stimulating competition among renewable energy developers provides a plenty of economic benefits across the country through creating jobs and yielding a positive budget impact in particular states. For instance, the solar PV installation industry added nearly 14,000 jobs in 2012 with more than 119,000 people working in solar-related industries nationally in 2012, representing a 13.2 percent increase over 2011 levels (SEIA 2013), and 75,000 full-

2 U.S. Energy Information Administration, October 26, 2016, https://www.eia.gov/todayinenergy/detail.php?id=28512 [Last accessed 2017 Jan 11].

3 Ibid.

time workers employed in the wind energy industry (Renewables, Report, 2013). The wind projects in Iowa, which generated more than 20 percent of its electricity from the wind in 2011, provided more than $ 19.5 million in annual property tax payments to state and local governments (Renewables, Report, 2013). The price-stability benefit offered by homegrown renewable energy influences the stability of business in general with little or no additional cost to consumers, which benefits the whole society. The uncertainties associated with natural gas and coal prices and ongoing fuel costs around the world make the issue topical. A hope to keep the costs down and the advantage of liberation from volatile domestic and global fossil fuel markets make state authorities develop renewable energy resources.

Programs supporting renewables are adopted at the federal and regional levels. A well-known law that first section is also known as Emergency Economic Stabilization Act, which was adopted in 2008, includes Division B – Energy Improvement and Extension Act of 2008 devoted to renewable energy incentives (Public Law 110-343, 2008). The law touches some issues as limitations to carbon emissions, expansion of biomass facilities, modification of rules for hydropower production, and development of tidal, solar and wind energy facilities, etc. The law extends tax credits to the facilities using renewable energy resources by providing them with so-called energy bonds.

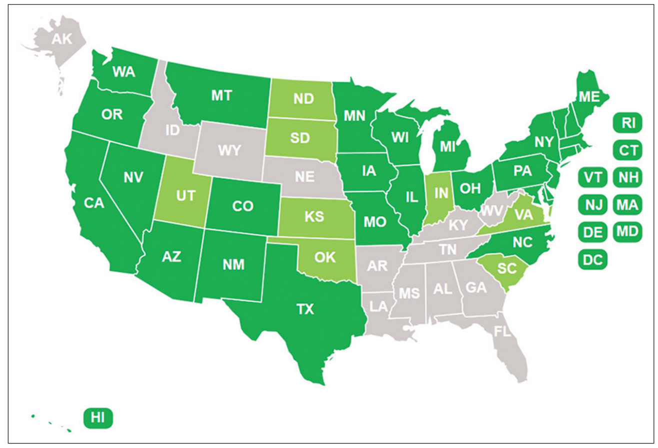
Some of the other laws adopted including S. 1595 – 113th Congress: Renewable Electricity Standard Act of 2013 and S. 1264 – 114th Congress: Renewable Electricity Standard Act of 2015 setting standards for renewable energy companies. These laws regulate work of energy retailers using renewables, impose requirements for the growing share of renewable energy, and define targets till 2039 and procedures for getting credits for the renewable facilities.

According to these laws, every state can join the federal program of renewable electricity development, adapt it to their conditions, and set their own standards. Figure 2 shows which state is in this global national project.

Table 2 characterizes to what extent each state participates in the program. It includes the states that defined targets on the percentage of retail electric sales or percentage-based cost caps for renewable energy capacities such as using wind, solar, geothermal or biomass energy. At the moment, 29 states and Washington, D.C. have adopted their Renewable Portfolio Standards, while eight states have set renewable energy goals. Iowa and Texas require specific amounts of renewable energy capacity rather than percentages, and Kansas requires a percentage of peak demand. The years of the establishment of these programs and the terms of reaching the indicators are shown in Table 2.

Table 2 shows that most states joined the restructuring program in the mid-2000s. South Carolina has planned the most modest goals of 2% renewable energy consumption by 2021. Hawaii demonstrates the most aggressive policy with a strict standard of 100% renewables by 2045. We should note that these values do not include hydroelectricity. Here, renewables include only wind, solar, biomass and some other natural sources.

Figure 2: Participation in the national program on developing renewable energy



*Color: gray – states and territories with no standard or target; light green – states and territories with a voluntary renewable energy standard or target; dark green – states and territories with renewable portfolio standards; **special territories under the U.S. control but not considered in the research are not included. Source: Jocelyn Durkay. state renewable portfolio standards and goals, 12/28/2016, National Conference of State Legislatures, http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx [Last accessed on 2017 Jan 17]

To make the review complete, Table 3 provides statistics on all the renewables by source including hydroelectricity as it is reported in all the references and reviews. The data on generating capacities per state is given in Table 3.

Table 3 shows that the most important renewable sources out of 6 considered are wind, solar, biomass and hydroelectricity. Although few new hydroelectric facilities have been built recently, in many states hydropower energy prevails. Six states generate renewable electricity mainly from biomass, four states actively use solar PV, and eighteen states use wind power facilities.

The power generating sector per state can be described in terms of the renewable share in total energy consumption, the dominant renewable source, the level of CO_2 emissions, and electricity rates and market-based policy (Table 4).

Table 4 shows that the renewables capacity differs greatly depending on the state. Each state develops their renewables according to their climatic conditions, but a single renewable energy source alone cannot guarantee absolute economic benefits. Notice that the electricity price is quite low in the states with dominant hydroelectric plants. The state of Washington is a bright example with the minimal price and the maximum share of renewables. However, electricity rates in New York and New Hampshire are above average in spite of a high share of hydroelectricity consumed. Besides, it is difficult to estimate the impact of wind facilities as well. There are some states try to make them dominant, but it does not seem to reduce the electricity prices or harmful emissions significantly. Nevertheless, the state with the greatest wind power consumed, Iowa, demonstrates prices close to the minimal level and very low emissions.

Table 2: Renewable portfolio standards or voluntary targets

State*	Established	Title	Requirement
AZ	2006	Standards	15% renewable energy as compared with general consumption by 2025
CA	2002	Standards	33% by 2020, 50% by 2030
CO	2004	Standards	30% by 2020
CT	1998	Standards	27% by 2020
DE	2005	Standards	25% by 2025-2026
HI	2001	Standards	30% by 2020, 100% by 2045
IL	2001/2007**	Standards	25% by 2025-2026
IN	2011	Goals	10% by 2015
AI	1983	Standards	105 MW
KS	2009/2015***	Goals	20% by 2010
ME	1999	Standards	40% by 2017
MD	2004	Standards	20% by 2022
MA	1997	Standards	15% by 2020 followed by 1%
MI	2008 2016	Standards	15% by 2021 (standard) 35% by 2015 (target)
MN	2007	Standards	25% and 26.5% for different suppliers by 2025
MO	2007	Standards	15% by 2021
MT	2005	Standards	15% by 2015
NV	1997	Standards	25% by 2025
NH	2007	Standards	24.8% by 2025
NJ	1999	Standards	24.5% by 2020
NM	2002	Standards	20% and 10% for different suppliers by 2020
NY	2004	Standards	50% by 2030
NC	2007	Standards	12.5% by 2021 for individuals, 10% by 2018 for municipal
ND	2007	Goals	10% by 2015
OH	2008	Standards	25% by 2026
OK	2010	Goals	15% by 2015
OR	2007	Standards	25% by 2015 etc.
PA	2004	Standards	18% by 2020-2021
RI	2004	Standards	14.5% by 2019, 35% by 2035
SC	2014	Goals	2% by 2021
SD	2008	Goals	10% by 2015
TX	1999	Standards	10000 MW by 2015
UT	2008	Goals	20% by 2025
VT	2005/2015**	Standards	55% by 2017, 75% by 2032
VA	2007	Goals	12% by 2022, 15% by 2025
WA	2006	Standards	15% by 2020
WV	2009/2015****	Standards	25% by 2025
WI	1998	Standards	10% by 2015
Washington, DC	2005	Standards	20% by 2020, 50% by 2035

*The special territories are not listed as we did not analyze their data; **Move from goals to standards; ***Move from standards to goals; ****Standards were repealed. Source: Durkay (2016). State Renewable Portfolio Standards and Goals, 12/28/2016, National Conference of State Legislatures, http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx [Last accessed on 2017 Jan 17]

Table 4 is an example of how the statistical data is being used in panel analysis that is based on the indicators given above for all the U.S. states for a period of 15 years.

4. RESEARCH METHODS AND STATISTICAL FRAMEWORK

4.1. Cluster Analysis

In order to cluster the objects, the method of self-organizing feature maps (or Kohonen maps) was used. The self-organizing map describes a mapping from a higher-dimensional data pile to a two-dimensional one on the basis of optimal weight coefficients selected for the input variables so that they would be most closely approximated to the output parameters. In this case, the output parameter is the state's GDP with all the other parameters used as input data. We assumed that if we got a cluster of the states with the highest GDP and the highest rate of renewable energy capacity, we could prove the development of renewables to be one of the key factors for economic growth. For further analysis, the estimates of the economic growth elasticity with respect to the state's energy consumption based on the use of renewables are done either for all the states or for the cluster with the highest renewable indicators.

4.2. Panel Data Analysis

The empirical estimation of the dependence between the state's economic growth and the level of renewable energy consumption was done based on four types of models: A pooled model, regression with one and two fixed effects and regression with random effects. The pooled regression alone does not allow us to take into account the state features, such as a different level of the socio-economic development (Booth et al., 2001). Even though we analyze a balanced panel, the estimates can appear ineffective or shifted. Notice that unobserved individual effects stable in time can lead to an inconsistent estimate by means of least squares. The reason is the correlation between the lag dependent variable and a random error, $\varepsilon_{it}=a_i+u_{it}$, where α is the unobserved individual effects. The inconsistency does not disappear when we use fixed or random individual effects.

This issue can be solved if we use the Arellano-Bond method (Arellano and Bond, 1991), which helps to solve the equation by means of the general methods of moments when we use first-difference equations to eliminate the unobserved individual effects.

The assumption is that the development of the renewable energy sector and the growth of renewable energy consumption might be the factors of economic growth. The general level of electricity rates on the state market, the volume of emissions, and a dummy responsible for restructuring in a particular state were chosen as determinants.

The equations can be written as follows:

$$Y_{it} = \beta_0 + \beta_1 * Y_{it-1} + \beta_2 * REC_{it} + \beta_3 * EPT_{it} + \beta_4 * ERS + \upsilon_{it} \quad (1)$$

$$REC_{it} = \gamma_0 + \gamma_1 * REC_{it-1} + \gamma_2 * CO_{2it} + \gamma_3 Y_{it-1} + \upsilon_{it} \quad (2)$$

Table 3: Renewable generating capacities by U.S. region, 2014, MW

State	Wind	Solar	Solar PV	Geothermal	Biomass	Hydroelectricity	Total
AL	0.00	0.00	0.00	0.00	16.86	83.14	100.00
AR	0.00	0.00	0.00	0.00	22.25	77.75	100.00
AZ	4.70	35.25	5.59	0.00	0.81	53.65	100.00
CA	19.44	28.65	4.13	9.78	5.02	33.00	100.00
CO	70.29	10.79	0.00	0.00	0.89	18.03	100.00
CT	0.00	23.75	0.00	0.00	52.50	23.75	100.00
DE	2.82	85.92	0.00	0.00	11.27	0.00	100.00
FL	0.00	9.28	4.38	0.00	83.08	3.27	100.00
GA	0.00	5.61	0.00	0.00	27.22	67.17	100.00
IA	97.40	0.00	0.00	0.00	0.39	2.21	100.00
ID	26.50	0.00	0.00	0.49	3.81	69.20	100.00
IL	93.90	1.42	0.00	0.00	3.63	1.05	100.00
IN	86.26	5.59	0.00	0.00	3.61	4.55	100.00
KS	98.74	0.00	0.00	0.00	1.03	0.23	100.00
KY	0.00	0.00	0.00	0.00	10.10	89.90	100.00
LA	0.00	8.40	0.00	0.00	66.80	24.81	100.00
MA	7.22	50.67	0.00	0.00	23.95	18.15	100.00
MD	14.69	19.74	0.00	0.00	14.97	50.60	100.00
ME	23.33	0.00	0.00	0.00	38.65	38.02	100.00
MI	64.71	0.00	0.00	0.00	19.82	15.47	100.00
MN	80.08	0.53	0.00	0.00	13.98	5.41	100.00
MO	44.12	9.89	0.00	0.00	1.52	44.47	100.00
MS	0.00	0.00	0.00	0.00	100.00	0.00	100.00
MT	20.17	0.00	0.00	0.00	0.12	79.71	100.00
NC	0.00	27.21	0.00	0.00	18.84	53.95	100.00
ND	75.14	0.00	0.00	0.00	0.40	24.46	100.00
NE	70.00	0.00	0.00	0.00	1.38	28.62	100.00
NH	18.81	0.88	0.00	0.00	31.02	49.28	100.00
NJ	0.52	83.53	0.00	0.00	15.20	0.75	100.00
NM	66.02	26.42	0.00	0.33	0.57	6.67	100.00
NV	5.80	27.65	2.44	23.87	0.11	40.12	100.00
NY	23.55	5.35	0.00	0.00	8.19	62.91	100.00
OH	50.35	11.81	0.00	0.00	22.92	14.93	100.00
OK	80.86	0.00	0.00	0.00	1.88	17.25	100.00
OR	26.25	0.71	0.00	0.31	3.45	69.28	100.00
PA	42.49	7.77	0.00	0.00	20.58	29.17	100.00
RI	17.31	0.00	0.00	0.00	76.92	5.77	100.00
SC	0.00	0.59	0.00	0.00	25.45	73.96	100.00
SD	33.39	0.00	0.00	0.00	0.00	66.61	100.00
TN	1.01	4.55	0.00	0.00	7.00	87.44	100.00
TX	90.24	2.11	0.00	0.00	3.32	4.33	100.00
UT	46.76	2.59	0.00	11.08	1.87	37.70	100.00
VA	0.00	0.60	0.00	0.00	54.75	44.65	100.00
VT	20.20	11.78	0.00	0.00	14.48	53.54	100.00
WA	12.54	0.16	0.00	0.00	1.72	85.58	100.00
WI	39.95	1.23	0.00	0.00	26.33	32.49	100.00
WV	62.05	0.00	0.00	0.00	0.23	37.72	100.00
WY	82.31	0.00	0.00	0.00	0.00	17.69	100.00
AK	12.42	0.00	0.00	0.00	2.40	85.17	100.00
HI	20.58	44.06	0.70	5.09	26.97	2.60	100.00

Estimates based on Beiter and Tian (2015) 2014 Renewable Energy Data Book, U.S. Department of Energy, Energy Efficiency and Renewable Energy, November 2015, http://www.nrel.gov/docs/fy16osti/64720.pdf [Last accessed on 2017 Jan 15]

Here:

Y_{it} – A natural logarithm of the real GDP in state *i* during time *t* at 2009 values;

REC_{it} – A natural logarithm of renewable energy consumption in state *i* during time *t*;

EPT_{it} – A log of the general electricity prices in state *i* during time *t*;

ERS – A dummy equal to 1 in case of restructuring and 0 if restructuring programs were not enacted or were suspended;

CO_{2it} – A natural logarithm of CO_2 emissions in state *i* during time *t*.

We assume that the level of the region's economic growth depends on the renewable energy consumption, the market electricity price and the process of restructuring the industry. In its turn, the renewable energy consumption depends on the environment pollution and the GDP during the previous period.

4.3. Statistical Data

The Kohonen map with clusters of similar objects was based on the 2014 data on all U.S. states, taking into account 20 indicators. They

Table 4: U.S. power generating sector per state, 2014

State	Renewable share	Dominant renewable facilities	CO_2 emissions, mln metric tons	Average electricity prices by sector (c/kWh)	Electricity industry restructuring till 2010
AL	14.2	Hydroelectric plants	123	9.75	No
AR	10.9	Hydroelectric plants	69	8.31	Suspended, 2003
AZ	9.9	Hydroelectric plants, solar facilities	93	9.81	Suspended, 2007
CA	11.5	Hydroelectric plants, solar facilities, wind facilities	358	15.99	Suspended, 2010
CO	8.9	Wind facilities	92	10.81	No
CT	5.8	Biomass	35	16.93	Yes
District of Columbia	0.7	N/a	3	11.85	Yes
DE	2.9	Solar facilities	13	11.25	Yes
FL	7.6	Biomass	228	10.84	No
GA	10.0	Hydroelectric plants	140	10.69	No
IA	26.3	Wind facilities	82	8.43	No
ID	29.8	Hydroelectric plants	17	8.19	No
IL	6.0	Wind facilities	234	9.51	Yes
IN	5.3	Wind facilities	207	9.11	No
KS	13.3	Wind facilities	70	10.48	No
KY	5.1	Hydroelectric plants	139	8.43	No
LA	3.7	Biomass	218	8.56	No
MA	6.1	Solar facilities	64	14.91	Yes
MD	5.5	Hydroelectric plants	62	11.79	Yes
ME	38.3	Hydroelectric plants, biomass	17	11.91	Yes
MI	7.2	Wind facilities	163	11.42	Yes
MN	13.7	Wind facilities	95	10.02	No
MO	5.0	Hydroelectric plants, wind facilities	132	10.59	No
MS	6.3	Biomass	64	9.95	No
MT	34.0	Hydroelectric plants	32	8.48	Suspended, 2003
NC	7.9	Hydroelectric plants	127	9.52	No
ND	17.3	Wind facilities	59	9.17	No
NE	16.3	Wind facilities	52	9.23	No
NH	19.5	Hydroelectric plants	15	15.07	Yes
NJ	4.0	Solar facilities	114	14.22	Yes
NM	6.9	Wind facilities	50	10.40	Suspended, 2008
NV	11.7	Hydroelectric plants, geothermal facilities	37	10.06	Suspended, 2003
NY	11.5	Hydroelectric plants	170	16.51	Yes
OH	4.0	Wind facilities	232	10.14	Yes
OK	10.1	Wind facilities	105	8.67	No
OR	50.3	Hydroelectric plants	38	8.51	Yes
PA	5.5	Wind facilities	245	10.20	Yes
RI	3.7	Biomass	11	14.25	Yes
SC	9.0	Hydroelectric plants	75	9.91	No
SD	35.5	Hydroelectric plants	15	9.44	No
TN	8.5	Hydroelectric plants	104	9.93	No
TX	4.7	Wind facilities	642	9.20	Yes
UT	3.7	Wind facilities, hydroelectric plants	65	9.09	No
VA	66.8	Biomass, hydroelectric plants	104	9.26	Suspended, 2007
VT	25.3	Hydroelectric plants	6	14.84	No
WA	47.1	Hydroelectric plants	73	6.80	No
WI	9.5	Wind facilities	101	10.98	No
WV	7.4	Wind facilities	98	7.65	No
WY	10.3	Wind facilities	66	7.83	No
AK	3.6	Hydroelectric plants	35	18.47	No
HI	10.8	Solar facilities	18	34.33	No

Estimates based on: Status of Electricity Restructuring per State, http://www.eia.gov/electricity/policies/restructuring/restructure_elect.html [Last accessed on 2017 Jan 15]; Beiter and Tian (2015) 2014 Renewable Energy Data Book, U.S. Department of Energy, Energy Efficiency and Renewable Energy, November 2015, http://www.nrel.gov/docs/fy16osti/64720.pdf [Last accessed on 2017 Jan 15]; Ranking: Total Carbon Dioxide Emissions, 2014, http://www.eia.gov/state/rankings/?sid=US#/series/226 [Last accessed on 2017 Jan 19] can be divided into following groups: (1) General characteristic of the state's economy and energetics; (2) The structure of power-generating capacity by the source of renewable energy; (3) The structure of energy consumption by economic sector; (4) The structure of energy resource prices by economic branch. The indicators include GDP, CO_2 emissions, average electricity rates by economic branch, net summer capacity, net generation, total retail sales, cumulated installed capacities of wind, solar, geothermal, biomass facilities and hydroelectric plants, total energy consumption of residential, commercial and industrial consumers and transportation, and total energy prices for these categories.

We analyzed dynamic panel data using statistical data for the period of 2000-2014, four indicators (real GDP, renewable energy consumption, CO_2 emissions, and average electricity prices on June for all the types of consumers) and the fact of the industry restructuring as a dummy variable. The data refers to 51 U.S. states.

As for the sources of data, we considered official statistical data and facts provided on the website of the U.S. Energy Information Administration. The most important documents we used were reports by U.S. Energy Information Administration, 2014, U.S. Energy Information Administration, 2016 and the 2014 Renewable Energy Data Book of U.S. Department of Energy (Beiter and Tian, 2015).

5. RESULTS

The results of our cluster analysis for all the U.S. states based on 2014 statistical data are given in Table 5.

Table 5: The U.S. states clustered by energy sector data of 2014 (average values)

Cluster	States	GDP*	EM	ARP	NC	NG
1	ID, IL, MT, ND, OH, SD, WY	202.41	93.57	8.69	15243.43	68459463.86
2	NE, NM, UT, WV	93.88	66.25	8.62	10351.25	49145401.00
3	AR, IA, MN, MS, SC	194.64	77.00	8.97	17159.20	65545861.20
4	WA	386.3	73.0	7.13	30949	116334363
5	CO, KS, MA, MD, NV, OR, TX	418.66	143.57	10.72	27690.71	100896872.00
6	DE, GA, IN, ME, MI, NC, PA	326.30	130.29	10.51	25280.14	102600550.57
7	NJ, RI, AK	201.17	53.33	15.61	7891.00	26791888.00
8	KY, MO, OK, TN, VA, WI	258.78	114.17	9.10	21862.00	77765921.17
9	AL, AZ, CA, CT, DC, FL, LA, NH, NY, VT, HI	466.47	115.18	14.74	25266.36	91117394.18
Cluster	**States**	**TRS**	**RW**	**RPV**	**RCSP**	**RG**
1	ID, IL, MT, ND, OH, SD, WY	53897744.14	1391.57	22.29	0.00	2.57
2	NE, NM, UT, WV	29019128.75	633.00	85.75	0.00	20.25
3	AR, IA, MN, MS, SC	58805983.40	1744.60	6.20	0.00	0.00
4	WA	92140777	3075	39	0	0
5	CO, KS, MA, MD, NV, OR, TX	97455952.43	3318.57	357.71	9.14	94.71
6	DE, GA, IN, ME, MI, NC, PA	92744021.14	722.57	219.00	0.00	0.00
7	NJ, RI, AK	29224664.67	26.67	483.67	0.00	0.00
8	KY, MO, OK, TN, VA, WI	84350510.17	825.67	45.33	0.00	0.00
9	AL, AZ, CA, CT, DC, FL, LA, NH, NY, VT, HI	87271998.27	763.64	1069.64	147.36	275.18
Cluster	**States**	**RB**	**RH**	**CR**	**CC**	**CI**
1	ID, IL, MT, ND, OH, SD, WY	70.00	1122.43	340.29	271.97	507.23
2	NE, NM, UT, WV	9.50	250.75	154.45	134.08	278.85
3	AR, IA, MN, MS, SC	339.60	603.80	305.00	238.94	555.52
4	WA	422	20977	481.7	376.5	566.8
5	CO, KS, MA, MD, NV, OR, TX	216.86	1648.86	513.61	466.16	1114.26
6	DE, GA, IN, ME, MI, NC, PA	481.29	844.57	566.39	416.21	710.47
7	NJ, RI, AK	105.33	147.00	241.80	245.43	200.00
8	KY, MO, OK, TN, VA, WI	308.67	1025.17	488.93	398.07	544.48
9	AL, AZ, CA, CT, DC, FL, LA, NH, NY, VT, HI	517.45	1991.45	481.84	439.52	639.91
Cluster	**States**	**CT**	**PR**	**PC**	**PI**	**PT**
1	ID, IL, MT, ND, OH, SD, WY	358.09	19.21	17.36	13.02	27.67
2	NE, NM, UT, WV	206.23	18.94	17.22	14.23	27.80
3	AR, IA, MN, MS, SC	371.72	23.28	19.28	11.69	26.33
4	WA	587.0	19.54	18.40	10.33	27.27
5	CO, KS, MA, MD, NV, OR, TX	762.34	23.72	21.04	15.56	27.12
6	DE, GA, IN, ME, MI, NC, PA	564.94	24.46	20.95	12.33	27.10
7	NJ, RI, AK	361.97	23.45	22.32	22.97	26.16
8	KY, MO, OK, TN, VA, WI	543.18	22.04	19.46	12.42	26.67
9	AL, AZ, CA, CT, DC, FL, LA, NH, NY, VT, HI	693.74	34.64	29.51	19.13	26.90

*GDP: Real gross domestic product per states (Billion Chained[2009] Dollars), EM: Total carbon dioxide emissions (million metric tons), ARP: Average retail price (cents/kWh), NC: Net summer capacity (MW), NG: Net generation (MWh), TRS: Total retail sales (MWh), RW: Cumulative renewable electricity installed capacity (MW), wind; RPV: Cumulative renewable electricity installed capacity (MW), solar photovoltaic; RCSP: Cumulative renewable electricity installed capacity (MW), concentrating solar power; RG: Cumulative renewable electricity installed capacity (MW), geothermal; RB: Cumulative renewable electricity installed capacity (MW), biomass; RH: Cumulative renewable electricity installed capacity (MW), hydropower; CR: Total energy consumption (Trillion Btu), residential; CC: Total energy consumption (Trillion Btu), commercial; CI: Total energy consumption (Trillion Btu), industrial; CT: Total energy consumption (Trillion Btu), transportation; PR: Total energy price (Dollars per Million Btu), residential; PC: Total energy price (Dollars per Million Btu), commercial; PI: Total energy price (Dollars per Million Btu), industrial; PT: Total energy price (Dollars per Million Btu), transportation

Authors' estimates

We distinguished nine clusters. Cluster 4 can be considered an outlying case as it includes only Washington. According to the key characteristics (GDP and renewable energy installed capacity), this state is closer to Cluster 9, which includes 11 states with the maximum average GDP and installed capacities of solar, geothermal, biomass energy and hydropower. Another feature of Cluster 9 is high energy prices for residents and commercial consumers, which can be explained by high consumer demand and the standard of living in these states.

Notice that some clusters (namely, Clusters 3 and 6) include objects with low GDP and installed capacities simultaneously. These clusters include 5 and 7 states respectively.

The weight of indicators in cluster analysis is defined automatically, so the high-weight coefficients of input parameters connected with renewable energy mean that their development is significant for the regional economy.

Our panel data analysis has revealed the dependencies shown in Tables 6 and 7. Table 6 estimates two models, Model 1 with one fixed effect and Model 2 with two fixed effects (including a temporary effect). Model 3 is described in Table 7, which provides the Arellano-Bond dynamic panel data estimation.

The model with fixed effects was chosen based on the Hansen test, with a Chi-square variable for Equation (1) being 39.34 and for Equation (2) 51.18. The null hypothesis that the over-identifying restrictions were rejected in both cases. Thus, we do not estimate the parameters of the regression equation with random effects.

Authors' estimates

Our estimates show that the state's gross regional product depends largely on that of the previous period. This fact emphasizes that the panel data should be estimated dynamically, which was done for both selected sets of data in order to test auto-regression. We see that the GDP depends on the renewable energy consumption in the state, with 1% increase in consumption giving 0.011% increase in GDP for 51 states and 0.0031% for 11 states.

The set of data for all the states demonstrates the importance of energy prices. The higher the rate, the lower the economic growth in the state. Growing prices cause an increasing in costs for manufacturers who have to scale down production, which has a bad effect on the state's economic growth.

The dummy variable was not significant for either set of data. We believe that restructuring processes influence the prices in the industry from the very beginning when they are formed. Restructuring has no direct influence of on the state's economic growth, though, which is stated by many researchers (Borenstein and Bushnell, 2015). Moreover, U.S. authorities support quite a few programs funding renewables irrespective of the restructuring programs.

Table 6: Impact of renewable energy consumption on economic growth

Coefficients	51 states (2000-2014, balanced panel, 714 observations)		11 states (2000-2014, balanced panel, 154 observations)	
	Model 1	Model 2	Model 1	Model 2
β_1	0.928*	0.924*	0.972*	0.982*
β_2	0.009*	0.011*	0.0061*	0.0031*
β_3	−0.023*	−0.041*	0.1362	0.1711
β_4	0.0065	0.0091	0.0116	0.0156
γ_1	0.0901*	0.0921*	0.0541*	0.0562*
γ_2	−0.2768*	−0.3011*	−0.6179*	−0.6289*
γ_3	0.0115*	0.0119*	0.0691*	0.0781*
Individual effect	Yes	Yes	Yes	Yes
Temporary effect		Yes		Yes

***,**, *significance at 1%, 5% and 10% levels

Table 7: Impact of renewable energy consumption on economic growth based on GMM (modified Arellano-Bond method GMM 5)

Coefficients	51 states (2000-2014, balanced panel, 714 observations)	11 states (2000-2014, balanced panel, 154 observations)
β_1	0.9944*	0.8673*
β_2	0.0174***	0.0209*
β_3	−0.0702**	−0.0258
β_4	0.0072	0.017
γ_1	0.9702*	0.8339
γ_2	−0.0659	−0.03192
γ_3	0.0165*	0.0551
Arellano-Bond test for AR (1)	z=−5.01 Pr>z = 0.000	z=−1.55 Pr>z = 0.121
Arellano-Bond test for AR (2)	z=0.19 Pr>z = 0.847	z=−1.55 Pr>z = 0.121
Sargan test of over identifying restrictions	χ^2 (36)=254 Prob>χ^2=0.000	χ^2 (36)=86.68 Prob>χ^2=0.000

***,**,*stands for 1%, 5% and 10% levels

Renewable energy consumption depends on its lag value similarly to GDP, which was demonstrated by both sets of data for 51 and for 11 states. We also observe inverse dependence between the level of emissions and renewable energy consumption. It is evident that large emissions stimulate the development of renewable energy sources in the state, but the higher the renewable energy consumption, the lower the level of emissions is. Thus, our inverse dependence testifies to the latter trend being stronger. For 11 states, the dependence between the growth of renewable energy consumption and the state's economic growth is stronger than for the larger set of data. We can explain it by the fact that the states with higher GDP can afford to fund more ambitious programs of developing renewables.

In order to evaluate dynamic panel data, we used lagged values of the regressor as instruments and obtained 39 instrumental variables for Equation (1) and 26 instrumental variables for Equation (2). The results are given in Table 7. The equation has high values of autoregressive parameters β_1 and γ_1, which may cause shifted estimates due to the weak instruments used (Blundell and Bond, 1998). This is why we used a modified Arellano-Bond generalized method of moments (Blundell and Bond, 1998; Lemmon et al., 2008; Hovakimian and Li, 2011).

Authors' estimates

In this model we reject the null hypothesis of AR(2) residuals being insignificant and point out that the Sargan test of over-identifying restrictions is valid as it is the test for AR(2) residuals. In order to estimate the equation based on the set of data for 51 states, we emphasize the importance of the level of renewable energy consumption. It shows the influence of the growth of renewable energy consumption on the dynamic economic in U.S. regions. For the data on 11 states, the significance of price unlike the panel data with fixed effects is not proved, but the influence of renewables on the states' economic growth is evident.

Finally, using the method of panel data with one and two fixed effects as well as the method of dynamic panel data we identified 6.144 pt

the positive influence of growing renewable energy consumption on the GDP growth. It proves the importance of renewables for all the U.S. states and for most developed 11 states obtained by the cluster method as well and testifies to the stability of the results delivered.

6. CONCLUSIONS

The economic impacts of the electric industry are great. The U.S. authorities try to ensure its steady growth by stimulating the industry in different ways. Recent decades have witnessed energy restructuring programs since the mid-1990s and federal support for renewable energy facilities provided since the mid-2000s. Not all the trends initiated by the federal government found implementation in the states. The programs of restructuring and federal legislation are carefully evaluated by each state in terms of the state needs and regional capabilities. Less than half of the U.S. states enacted the restructuring programs, and only 29 states out of 51 actively taking a part in developing renewable energy resources. Some of the states joined the program but did not set strict standards or targets. It is connected with significant regional differences caused by various economic factors, such as the state economic conditions, operating conditions, local needs, natural resources availability, and the will of regional powers. However, there is a modern trend evidence to increase the share of renewable energy facilities in the general electricity consumption, which was initiated by federal authorities at the end of the recession of 2008 and it is still supported. It aims at economic growth and has a certain positive impact, which is shown by our analysis.

In order to model the situation in the U.S. electricity sector by region and evaluate its influence on the economic growth, we considered a number of factors and conditions. Having the same aim in views, different states suspended the restructuring programs because of doubtful results, but some states demonstrate positive results with more than half of the states are being active in this direction. Modern programs on developing renewables have their own features and target goals in different states. Common aims are usually connected with the environment protection and support for residents and businesses. Thus, the main parameters of our model include the indicators of economic growth, electricity rates, the share of renewable electricity consumption, the level of emissions, and participation in restructuring. We estimated the dependencies between the factors using the method of panel data analysis with some modifications preceded by the cluster analysis aimed to define the state differences according to the economic situation and energy facilities.

Our empirical analysis has shown that during the period considered the increase in renewable energy consumption appeared one of the factors of economic growth in U.S. states. It can be explained by improved technologies and an active federal support for the industry. The rate of the growth depends on the electricity rates. Cost reduction stimulates manufacturing, which boosts the economic growth. We also noted an evidence reverse dependence between emissions and development of renewable energy facilities. Restructuring programs did not influence the economic growth directly. All these interactions were shown by means of models considering fixed effects and dynamic panel data models, which included sets of data for 51 states.

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