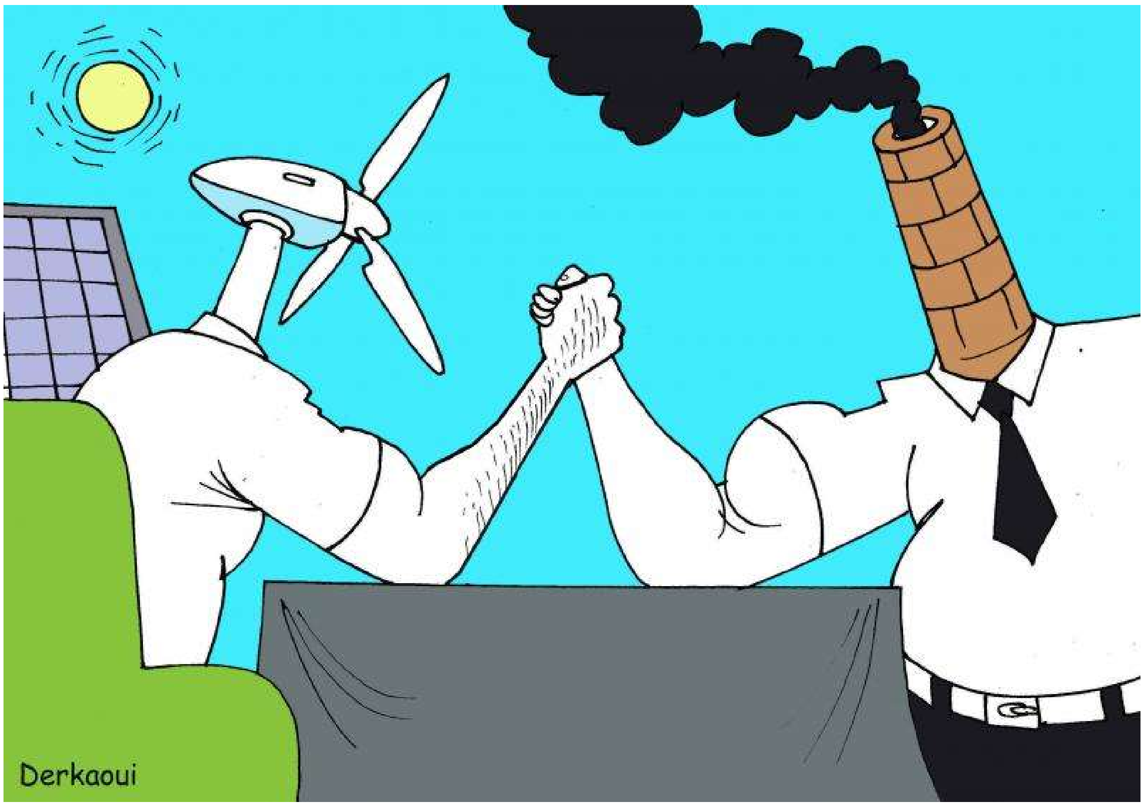
Regional Competitiveness in the Renewable Energy Sector; A quantitative estimation of the effectiveness of policy



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Abstract

Despite the rising pressure of climate change and governments around the world to decrease carbon emissions, the Renewable Energy sector is still relatively non-competitive in a free market environment. This sets the stage for research on the influence of policy implementation that aims at fostering Renewable Energy competitiveness. The main focus of this paper is to address policy implementation and its effect on competitiveness of Renewable Energy markets, by using quantitative data on Renewable Energy policies and other socio-economic factors from the states of the U.S. Spatial spillover effects are investigated by using spatial econometric models to further expand the understanding of dynamics in the Renewable Energy Sector. Policy diffusion is the main argument behind spatial spillover effects, where states resemble policies adopted by other states.

Clear evidence for the desired effect of policymakers to increase Renewable Energy competitiveness is not found in this research. The presence of local capital and a strong labor force in a region dominates the effect of the accumulation of Renewable Energy policies implemented. One form of policy, financial incentives, is found to have an indirect positive effect on competitiveness in other states. Endogenous spillover effects are found within the dataset, being positive in the short-run and negative in the long-run. The findings call for more attention to the quality of the region-specific policy landscape and the dynamics of the Renewable Energy sector, in order to increase competitiveness in the Renewable Energy Sector.

Inhoud

1. Introduction

Governments around the world are supporting the employment and development of renewable energy (RE) sources as a way of dealing with climate change and the effects of carbon emissions on the environment (Bersalli et al., 2020). This is in line with the new targets as set by the Biden Administration to 'achieve a 50% reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030, in order to tackle the climate crisis' (The White House, 2021). Despite rapid technological progress, generation of renewable energy is still more expensive than traditional (fossil) energy, causing a competitive disadvantage for the RE sector in a free market environment (Bento et al., 2020). Because of this discrepancy, a growing debate on the appropriate approach towards implementing policies to foster competitiveness of the RE sector is arising. Existing literature focuses on the most efficient 'policy mix' in order to reach these goals (del Rio & Bleda, 2012). Besides an important factor in reaching environmental goals, RE development is related to economic growth and energy security (Inglesi-Lotz, 2016), but also job creation (Frondel et al., 2010).

The challenges and opportunities that arise with the transition towards a greener energy-mix encourage scientists to investigate the underlying principles of competitiveness in the RE sector. Understanding the societal and scientific relevance of fostering regional competitiveness in the Renewable Energy sector involves understanding of the energy industry and its influence on economic geography. It emphasizes the importance of policymakers to focus on the growth of competitiveness of the renewable energy sector to strengthen the economy as a whole. Debates arose in the U.S. about the shift towards Renewable Energy and the possible economic gains or losses related to this shift. The discussion of the economic geography of decarbonization will lead to the formulation of the research question of this paper.

Energy access, throughout history, has been a driving factor for the location of economic activity. The geographical pattern of industrialization in 19th century Europe for example, is closely related to geological distributions of coal deposits (Bridge et al., 2013). Even today this image resembles reality, as the distribution of ferrous metal facilities closely mirrors that of active coal mines (some exceptions). The reason for this is the high transportation costs of the fuel, making it more efficient to produce steel at the site of the coal deposits.

Even though the emergence of oil in the 20th century with lower transportation costs allowed for industrial activity to move away from the sources of extraction of energy, the geographical constrains remained. This has to do with the emergence of oil refineries, oil is a product that needs to be refined to commercially attractive sub-products like diesel and petrol, causing industrial consumers of crude oil products to locate alongside those refineries. As location decision making theories like the Weber Triangle and New Economic Geography suggest, firms make their decision based on transportation costs, making geography important (McCann, 2013).

Since the emergence of new, renewable sources of energy is occurring, fossil fuels will play a diminishing role in the energy mix. Sources of energy capture, conversion and distribution are going to change, making way for a new topography of economic activity. Constrains as laid upon by deposits of fossil fuels are no longer a factor. The question is to what extend this new topography will differentiate from the current state (McWilliams & Zachmann, 2021).

Given the entanglement of the geography of decarbonization and economic development, and the rising debate of policymakers on how to deal with a changing energy landscape, this article analyzes the proxies for regional competitiveness in the Renewable Energy Sector, with a focus on the implementation of RE policies. The states of the US are used in a panel data set to estimate for the influence of policies and other factors affecting competitiveness. As will be discussed later in this paper, spatial spillover effects of implemented policies are commonly referred to in policy literature. Spatial spillovers can help explain a greater part of the variance in econometric models and are therefore included in this research. Spatial models, an estimation technique that has barely been adopted within the existing body of literature on the RE sector, will be used to estimate the influence of adopted policies over time, and the spatial spillover effects of policies or other region-specific factors in a certain state on other states. Given the focus on spatial interactions between the study objects in the dataset, the main research question of this paper is twofold:

> *1. In the states of the U.S., to what extent do implemented Renewable Energy policies have an effect on the competitiveness of the Renewable Energy sector?*
>
> *2. To what extend do these effects spill over towards other states?*

1.2 Content

In chapter 2 the existing body of literature that is relevant for this research is analyzed and discussed. The relevance of the topic is elaborated on more thoroughly. To be able to investigate the influence of policy and other factors on RE competitiveness, the definition is analyzed. Economic geographical theories are used to get a clear understanding of competitiveness, with a focus on specific characteristics of the RE sector. This is followed by an analysis of the currently implemented landscape of RE policies in the states of the U.S. This way, an understanding of the way policymakers try to use policy tools to strengthen the competitive position of a regions RE sector can be created.

In section 3, characteristics of the U.S. energy markets are discussed. In the next section, theoretical underpinnings for the usage of spatial econometric models in estimating for policy effectiveness are set out. Section 4 elaborates on the usage of spatial models in estimating policy effectiveness, explains the used methodology of the research, and clarifies the selected variables included in the model. Section 5 presents the outcomes of the models, and compares them with the expected results as stated in the hypotheses. Section 6 entails the conclusion of the paper, and section 7 reflects on the research and its limitations.

2. Literature Study

2.1 New Economic Geography of Decarbonization

The first part of the literature study elaborates on the relevance of a competitive regional RE market. As mentioned in the introduction, the redistribution of energy sources and economic activity is of major importance for policy makers. There are a few factors that alter the extent to which industrial relocation occurs as a consequence of decarbonization of energy. First of all, the location-specific differences in the costs of capturing (clean) energy determine location-decisions of firms. Relative costs, or the availability of solar and wind energy, will determine the geographical location of energy-heavy industries. Besides that, the cost of capital is going to be influential, as renewable energy sources rely on capital more heavily than fossil fuel extraction which relies on operation costs (Lantz, 2009).

Secondly, transportation costs of energy will drive the economic incentives for the heavy industry to relocate or not. Transportation costs will determine whether a firm relocates or not. Several factors, for example investments in infrastructure to prevent congestion and bottlenecks in the power grid, determine the strength of this correlation. While price discrepancies will lead to relocation, mitigating factors like market design choices can soften these price discrepancies, influencing the outcome of geographical location decision by firms (McWilliamson & Zachmann, 2021). Clean gases need to be taken into account as well, since transportation costs of those secondary products of clean energy sources, as with oil and diesel, could alter the geographical composition of economic activity too. The Weber Triangle describes how important it is to estimate the costs of energy transportation as opposed to final product transportation (McCann, 2013). Is it cheaper to transport a tonne of steel or the energy to produce one tonne of steel? This will be a vital question in the redistribution of economic activity after decarbonization happened. An example is the fact that it is still unclear how expensive it will be to transport hydrogen, compared to transporting the end-product.

Lastly, the stickiness of existing agglomerations of energy sources and heavy industries needs to be accounted for. Economic activity tends to agglomerate around initial capital and human investments (Malecki, 2002). Numerous writers in the field of economic geography talked about the subject of positive externalities and agglomeration economies. In other words, will the existing geography of energy stick?

While it is unclear to what extend decarbonization of energy will lead to a new landscape of economic activity, it is certain that policymakers should emphasize a focus towards fostering regional competitiveness of the Renewable Energy sector. Not only does this benefit the environment, or the sector itself, it can also benefit the regional economy entirely in the long run.

2.2 The theoretical framework behind competitiveness

In order to conduct empirical research on the competitiveness of the Renewable Energy Sector, it is of major importance to define competitiveness. What does being competitive as a firm mean on a theoretical level? How can competitiveness be measured? What characteristics can be described towards competitiveness in the Renewable Energy Sector specifically? And how can those attributes be measured quantitatively?

Firstly, the theoretical underpinnings of competitiveness are discussed. Siudek et al. (2014) analyze the theory of competitiveness in a literature review. The article stresses the fact that an attempt of creating one common definition of the concept is doomed for failure, since it can be reported to an individual product, a firm, a region, a sector, or even a whole nation. Different scales and points of views alter the way competitiveness is described.

Theories linked to competitiveness can be divided into three main schools of thinking. The Classical School, the Neoclassical, Austrian or Institutional School, and the Contemporary School (Siudek et al., 2014; Fang et al., 2018). These different schools are discussed here because it shows the development of how scientists think about and implement competitiveness in their research. Classical economic thinkers focus on the macro-level of competition, where nations and regions compete with each other. The origin of attempts to explain international trade and its incentives stem from the work of Adam Smith, who attributed competitiveness to the absolute advantage countries have over others when they produce goods at the lowest costs. A country should focus on producing such products, while importing products they don't have a comparative advantage in (Sawyer, 2017). David Ricardo built upon this theory by addressing the fact that a country can be competitive and benefit from trade even if it lacks absolute advantage. Relative advantage over other countries can be sufficient to sell abroad (Ricardo, 1821). Moreover, Heckscher and Ohlin later expressed competitiveness as the abundance of local production factors. Countries with local capital abundance will focus on capital-intensive products, while labor-intensive products are produced by countries with an abundance of labor. International trade compensates for the uneven geographical distribution of factors of production (Leamer, 1995). Classic economic theories focus on the reduction of the price of a product in order to create a comparative advantage. Regarding this paper, the Renewable Energy sector still exerts a disadvantage compared to fossil fuel generated energy, since it is more expensive. The macro-focused view of competitiveness, which states that creating a comparative advantage can be achieved solely by reducing the price, is in contrast with the growing RE sector. Policies that shield RE projects from competition, like feed-in-tariffs, investment tax credits and subsidies, explain the increasing competitiveness of the RE sector.

Neoclassical economists have shifted the focus from a comparative advantage in terms of factors of production of countries towards micro-level decision-making processes by firms. Competitive advantage is obtained through the ability of a firm to create utility for a customer. As a product or service is not homogeneous and the perception of the customer towards it matters, simply reducing the costs and increasing productivity is not enough to sustain competitiveness (Hunt, 2000). Building upon the notion that perception matters, neoclassical economic thinkers address the importance of firms to improve and to innovate (Siudek et al., 2014). The theory of effective competition (Clark, 1961) suggests that innovation motivates firms to compete in order to sustain and grow in the market. Technological progress assures economic growth on the macro-level.

Elaborating on innovation, Evolutionary Economics is another strand of thinking that suggest that the crucial aspect of a firm's survival is the constant adjustment to its environment through innovation and by altering the composition of garnered resources. Schumpeter (1950) addressed the importance of innovation and entrepreneurship in fostering economic growth and technical change. He furthermore states that large firms and agglomerations of firms are more prone to creating incentives to innovate. Later these notions have been combined within the field of economic geography, when trying to explain the spatial evolution of regions and their ability to generate new varieties in terms of new technology (Boschma & Lambooy, 1999). Knowledge spillovers and agglomeration economies play a significant role in these dynamics. Renewable energy is a relatively new industry, which makes innovations and knowledge interesting to investigate. In the case of RE, subsidies are often designed to increase supply in the growing industry, by shielding them from lower-cost, non-renewable energy producers. This is in order to increase economies to scale and further strengthen innovation within the sector (OECD, 2022). Following the notion of neoclassical thinkers of competitiveness that competition is more than a low price, and innovation could lead to more competitive RE markets, policy is an important driver of competitiveness of the RE sector. Furthermore, as neoclassical thinking addresses evolution of products and innovation as being important drivers of competitiveness, spatial spillover effects are interesting to investigate because innovation and scale economies are prone to spatial spillovers to neighboring economies, as will be discussed more thoroughly later.

In the next section, two of the most influential and most discussed theories of competitiveness are discussed, which both can be classified within the Contemporary School. Although both thinkers emphasize the difficulty of constructing an all-compassing definition of competitiveness, Porter and Krugman both constructed contemporary models and ways of thinking in which regional competitiveness is embedded.

2.3 Regional competitiveness

As discussed in the introduction, policy choices by local governments concerning renewable energy are of major importance for regional growth of both the renewable energy sector, as well as other energy consuming dependent sectors. New economic geography of decarbonization is changing the topography of economic activity, giving opportunities for regions to grow, or hazards to lack behind.

New Economic Geography (NEG), a spatial equilibrium model created by Paul Krugman, is a widely incorporated theory in competitiveness research, as well as energy economics. In his theory, which is originally a location theory of production, Krugman argues for agglomeration or concentration as being a driver for growth of a region. He mentions centripetal and centrifugal market forces, that work on both firms and workers. For example, the proximity of other firms leads to a higher demand, which is called the home market effect. It also creates agglomeration advantages such as knowledges spillovers. On the other hand, proximity of more firms increases competition for labor. Moreover, agglomerations lead to congestion costs, which leads to spreading of economic activity (Brakman et al., 2005). The freeness of trade, or transport costs, that increase over distance, are also included in the model and influence the spreading or concentration of economic activity.

The NEG way of thinking creates interest in the implementation of agglomeration economies such as knowledge spillovers, existing markets, and present labor when spatially assessing economic activity. Also, it points out that price discrepancies could alter the behavior of workers and firms, especially in a sector where costs of capital are very high like the RE sector, as mentioned by Lantz (2009). As discussed before, emerging markets often establish themselves close to existing clusters of invested capital and human investments. Sunk costs of capital investments are also referred to as spatial embeddedness. Within energy technologies, capital investments entail the built environment and infrastructure of energy capture, conversion and consumption (Bridge et al., 2013). These initial costs of capital are a big hurdle for RE initiatives, and locally present capital can overcome this hurdle. In line with NEG, the relative price of capital in a region can exert an influence on competitiveness of the RE sector.

Policies that change the economic feasibility of the RE sector could lead to a new topography of the energy sector and its dependent sector, as discussed in the introduction. In the case of the electricity market, altering the relative price of Renewable Energy by implementing policies such as feed-in-tariffs or financial incentives could lead to a diversification of the spatial distribution of economic activity, within the RE sector and beyond (OECD, 2022; McWilliams & Zachmann, 2021). NEG gives reasons to believe that spatial spillover effects are present in competitiveness in the RE sector and the role of policy and should be implemented in the models used.

Porter referred to competitiveness as being dependent on productivity. His Diamond Model describes four underlining conditions that drive global competitiveness of companies, namely factor endowments, demand conditions, related industries or clusters, and the firm's strategy, structure and rivalry (Fang et al., 2018). Policymakers are interested in the model by Porter, since it offers the possibility to measure differences amongst regions or countries (Grassia et al, 2022). Furthermore, Porter includes luck and the government as affecting factors towards competitiveness, making room for policy to be influential (Bakan & Dogan, 2012). According to Porter, in order to be successful in a market, firms need to have a sustainable competitive advantage that is based on a strong utilization of the four components of the diamond of its home country (Rugman & D'cruz, 1993).

The argument for Porter when looking at comparative advantages of industries, is that the four determining factors influence each other, and their relationship is better characterized by multiplicative than by additive. This means that the imaginary surface of the diamond in comparison with other regions, countries or states represents the competitiveness of that region (Dogl et al., 2012). The effect of policies on the RE sector can alter the composition of the diamond, and with that the competitiveness of a regions RE sector. Policies that alter the economics of RE projects can influence the size of the diamond, for example when improving demand conditions, which will be discussed in section 2.6. Furthermore, policies in neighboring states can affect the local competitiveness of the RE sector, since related industries or clusters is one of the conditions for competitiveness. Porters Diamond model underlines the mechanisms that will be investigated in this research.

2.4 Other definitions of (regional) competitiveness

Besides the writers that wrote about competitiveness, a couple of definitions by different organizations are found and compared with the literature. The World Economic Forum (WEF) describes international competitiveness as 'the ability of a country or company to produce more wealth than its competitors under a world market equilibrium condition, thus international competitiveness is deemed to be the unification of competitive assets and competitive procedure (Browne et al., 2014). The OECD adds to that by mentioning that besides the ability to produce services and products under international competition, capacitating for growth of GDP and living standards should be included when addressing competitiveness (Grassia et al., 2022). The second definition considers other factors that attribute to well-being. Although this is obviously an important part of the energy transition and the fighting against climate change, this paper does not imply well-being as a quantitative measure. It simply supposes that a more competitive RE sector is ultimately better for well-being of present and future generations well-being.

The World Economic Forum (WEF) describes regional competitiveness as 'the set of institutions, policies and factors that determine productivity of a region' (Schwab et al., 2016). Again, the quality of the institutions and policies play a role in regional competitiveness according to the WEF. This solidifies the argument for this paper to investigate to what extent this is true.

2.5 Competitiveness in the Renewable Energy Sector

In the next section, comparable studies that focused on the relationship between policies and regional competitiveness in the renewable energy sector are discussed. In order to get a grasp of the efforts that have been done within the field of competitiveness and renewable energy, similar papers are analyzed and compared with the literature found on the topic.

A relevant study (Menz & Vachon, 2006), tried to estimate the influence of green power policies on wind power development in the United States. It investigated this by analyzing both the effect of a number of different implemented policies as well as the amount of years that each policy is implemented in a certain state. This way, the paper aims at capturing long-term cumulative effects of policy as well as temporary spikes. Wind power development is measured in both absolute indices, as well as growth indices, that indicate the installed wind capacity and relative growth in a certain time period. Lastly, the number of large Wind Energy projects are used as a final dependent variable. The wind technical potential per state is implemented to control for differences in resources in a given state. The wind technical potential is corrected for urban and environmentally sensitive areas, proximity of transmission lines, problematic landscape, and various land-use restrictions. Through hierarchical linear regression, the relationship between policy and wind energy development are measured. Besides the fact that this research is conducted in 2006, the model lacks a time-component in the form of panel data, as well as a geographical component in terms of spatial spillover effects.

Contributing to the implementation of the diamond model to competitiveness research in the RE sector is the paper by Fang et al. (2018). It assesses national competitiveness of the renewable energy sector in G20 countries, by analyzing the resource, economic, industrial and regulatory factors in the sector. It draws upon the Diamond Model by Porter, by creating an analytical framework for assessing national competitiveness. As indicated by this model, competitiveness of an industry lies in four broad categories: factor conditions, market conditions, related and supporting industries, and firm strategy, structure and rivalry, as discussed prior. The paper emphasizes factors that are specifically interesting when assessing the renewable energy sector. Geographical determinations and natural endowments of renewable energy sources, given their highly spatial and temporal heterogeneity, should be included in the Diamond model. Even though natural endowments play a huge role in the ability of the region to accommodate RE projects, this research is focused on the variance of competitiveness despite natural endowments. Therefore, natural endowments will not be included in the model. Furthermore, the long return to investment of Renewable Energy sources makes capital of major importance in the industry. The role of governmental investments is hence important to acknowledge and estimate in the model. The size of the labor force, lastly, reflects to some extent the scale of the industry, because of the labor-intensive characteristics of the industry. Building upon the Diamond Model, this paper contributes to the field of competitiveness in the renewable energy sector by emphasizing characteristics of the industry, and by creating a fitting index. Both capital and labor are important factors considering the RE sector. Both can be included in the models, since they represent characteristics of the RE sector.

Assessing the influence of renewable energy policy on regional competitiveness requires the implementation of a temporal component, in order to account for changes over time. Liu et al. (2019) make use of a panel data set, containing 29 OECD countries with data from 2000 to 2015. This, combined with the novelty of using a combination of aggregate and specific policy measures as explanatory variables, makes this paper add to the scientific realm of competitiveness is the renewable energy sector. It uses the total installed capacity of Renewable Energy sources as a proxy of competitiveness, and finds that synergy effects occur among different policies, implicating that the majority of the aggregated policy measures have a positive effect on the installed capacity of renewable energy. This insight can be used in this paper, because an aggregated policy implementation is founded to be beneficial in fostering RE competitiveness. Furthermore, the implementation of a time-dimension can be important in increasing the explanatory power of the models used. Policies that are implemented will not have an effect immediately. This takes time, as the effects of implemented policy does not show immediately.

Similar, Carley et al. (2009) include state-specific electricity market trends in their time-period model with fixed effects. Besides the main policy variable, which is a dummy variable covering Renewable Portfolio Standards, they include the number of Renewable Energy policies in a state implemented, in the form of two separate policy indices, ranging from 1 through 4. Those two groups of policies are tax incentives and subsidy policies. This paper estimates the effectiveness of these policies, by measuring the natural log of the share of renewable energy in the total energy mix, as well as the absolute amount of RE generated per year per state. Again, this paper does not compare different actors in its dataset when it comes to competitiveness, as it simply uses output as its dependent variable. It does use another variable, the share of RE in every state's total energy mix. This represents the competitiveness of the RE sector as opposed to fossil fuel generated energy. Carley et al. (2009) do advocate for a time dimension in their discussion, since implementation and maturing of policies takes time.

Kilinc-Ata (2016) used a panel data set of 27 EU countries and 50 US states over 1990-2008. An econometric model is then used to find out what the influence is of different policies on RE deployment. He used dummy variables for four different policy instruments, namely Feed-in Tariffs, quota's, tender and tax incentives. The explanatory variables were categorized in terms of their role in Renewable Energy development. Substitute and security variables, the ability to substitute for RE and the ability to import energy, have a negative impact on Renewable Energy development, whereas Economic and

Environmental variables, GDP growth and consumption of electricity and the emission of carbon dioxide, have a positive effect. The model estimates the effect of these factors on the ratio of renewable energy as the percentage of electricity capacity. A fixed effects regression model shows significant improvements of RE deployment with FIT's, tender and tax policies, but no significant effect for quota's. This research used similar control variables as the factors used by Porter in his Diamond model. However, the main focus in Kilinc-Ata (2016), just like in this paper, is the policy variable. Kilinc-Ata (2016) did not take into account the cumulative effects of policies implemented, as only dummy variables were used. This paper tries to capture the accumulative nature of policies, by creating ordinal variables for policy.

Przychodzen & Przychodzen (2020) found a significant relationship between economic growth and a growing renewable energy generation in a panel data study of 27 transition economies over a 24-year time period. They also found a positive relationship between unemployment and renewable energy generation growth. According to this study, the renewable energy sector can serve as an effective way of reducing excessive unemployment by creating additional job opportunities. In combination with the labor-intensive character of the sector, this makes a rising unemployment rate positively stimulating the generation of renewable energy, and with that competitiveness in a certain area. Regarding the influence of policy, they found governance financing to have a fundamental role in the effective transition towards a low carbon economy. This in contrast with competition enhancing policies, which hindered production of renewable energy. Although competitiveness within the renewable energy sector positively enforced production, this finding suggests that the way of implementing competition policy legislation is critical for the renewable energy sector. Zooming in on the states of the U.S. it is interesting to investigate if certain strands of policies do foster competitiveness of the RE sector, especially since theoretical considerations imply that policies do have a positive influence.

A big hurdle to deployment of RE projects is their high initial costs of capital, like mentioned before. High initial costs of capital create a long return on investments, making technical knowledge an important driver of RE competitiveness (Xu et al., 2019). Given this fact, one would suggest that the level of R&D investments in a state increases RE competitiveness. However, Przychodzen & Przychodzen (2020) erased the role of R&D in fostering renewable energy production from their model due to multi-collinearity. Nesta et al. (2014) researched the effect of R&D and also failed to find a significant correlation between R&D and Renewable Energy production.

2.6 Renewable Energy policies

Now that the economics and specific characteristics of the RE sector are clarified, the existing measures that governmental bodies take in order to change these economics can be discussed. Since the states of the U.S are the research area of this paper, the focus will be on policies implemented on a state level in the U.S, as this is where most RE policies are implemented (Kobos et al., 2006).

Firstly, regional competitiveness, and with that regional productivity, since productivity is seen as a major indicator of revealed competitiveness, has been a prime target for policy intervention (Kitson et al., 2004). Especially in an emerging market as the renewable energy sector, where besides environmental benefits for society as a whole, in-state economic benefits, job-creation for distributors, installers and manufacturers, and reduced consumer electricity costs and grid security for consumers could be realized (CESA, 2009). In the following section, the different tools used by states to grow the renewable energy market and to drive clean energy deployment and competitiveness in it are discussed.

The most significant and most frequently used policy tool for states in order to foster growth in the renewable energy sector is the Renewable Portfolio Standard (RPS). This represents a required minimum share of electricity generated by suppliers that is originated from a renewable source. In the U.S., 29 states have established a form of this policy, varying in strictness and implementation (CESA, 2019). Throughout recent years, states have set more aggressive RPSs, partly because improved technologies have increased the economic case for renewable energy sources, making higher standards more plausible and reachable (Barbose, 2019). Since the mandatory minimum amount of RE generation as opposed by RPS policies, competitiveness of the RE sector is expected to improve in states with a higher RPS. However, it is not perfectly clear if the correlation between RPS and growth of RE incentives is significant, as found by Yin & Powers (2010).

Feed-in-Tariffs (FIT) are above-market prices that are guaranteed to utilities for their generated renewable energy and can be used to meet the policy goals of states. These tariffs encourage the development of RE resources, because prices of renewable energy are, however improved, still less competitive than fossil fuel generated energy (Couture & Cory, 2009). They can both benefit ratepayers and RE developers, because a guaranteed payment for RE development allows developers to sell RE at a more competitive price. A sidenote is that, as discussed before, the high initial cost of capital for RE development is not addressed (Lantz, 2009). Given these high initial costs of capital, mentioned earlier as an important feature of the RE market, FIT's may not help in encouraging new RE initiatives to be formed. Moreover, FITs could lead to suboptimal siting of new RE development projects (Klein et al., 2008).

Public Benefit Funds and financial incentives as grants, loans, rebates and tax credits, are used to alter the economics of RE investments and energy efficiency, in order to make investments in RE development more attractive. In the past three decades the funding and tax incentive programs of states in the U.S. have been diversified in order to target specific markets and create a greater sectoral coverage (EPA, 2022). Other than FIT's, Public Benefits Funds and financial incentives do target the relatively high initial costs of capital of RE projects, showing that different policies are targeting different hurdles that prevent the RE sector from being competitive. From this follows the notion that cumulative benefits of implementing RE policies can be of importance for policymakers. Moreover, Lund (2009) found this in a search for the effect of policies on RE development, as he describes the learning curve that occurs when governmental bodies search for the best possible policy-mix. Hence, as will be explained later, the variables used to measure effectiveness of policies in this paper will be adjusted to this phenomenon.

Net metering is a mechanism that credits owners of solar energy systems, since it allows them to track the amount of (renewable) energy they use and provide to the grid. 38 states have adopted mandatory net metering rules, allowing the demand for solar energy to increase. This benefits customers, but also installers and manufacturers of solar systems (SEIA, 2017). It requires utilities to accurately check for the usage and generation of RE. Since net metering incentivizes costumers to install solar panels, demand for solar installations will increase. This is in line with the notion of the Diamond model and NEG, that demand conditions foster competitiveness and economic activity of the sector respectively.

Output-based Environmental Regulations are used to set up emissions limits per unit of productive energy output of a process, with the goal to encourage energy efficiency and renewable energy use. It is also used to foster fuel conversion efficiency, for example to use the heat produced in one process to generate energy for another process. It incentivizes firms to reduce electricity use. This might lead to a decrease in demand for electricity. However, as both fossil-fuel-generated electricity and RE both suffer from this, relative competitiveness will not decrease for the RE sector.

Lastly, Interconnection Standards is a set of processes and requirements for electric utilities that prescribe how they treat renewable energy sources, in order for those generation sources to be able to reduce uncertainty and delays for RE systems to obtain electric grid connections. Standard procedures can ease the process of obtaining connections to the grid by delineating technical requirements and processes for utilities, so that RE development becomes more feasible (EPA, 2022). Again, initial costs of capital are reduced, as well as labor-intensive work required for the technical requirements of installation and connection to the grid. This might also increase competitiveness of the RE sector.

2.7 Spatial spillover effects of competitiveness in the RE sector

A couple of researchers have implemented the spatial dimension of competitiveness in the RE sector. According to Kuik et al. (2019), competitiveness is the ability to sell goods and services and to stay into the market. This is very hard to measure, hence one should focus on its determinants and consequences. The determinant of competitiveness is productivity, while consequences entail stock value, volume of activity or market flow, or trade flows. Kuik et al. (2019) implemented a Gravity model that models policy impacts on exports of solar- and wind related products. The gravity model takes into account various geographic variables, including distance, population size and trade agreements. They found a significant influence of policy on comparative advantage in the RE sector. However, no spatial spillover effects were found in this paper, since this was not the main interest. They used the gravity model to improve the explanatory power of the model, through incorporating trade linkages, geographical distance and other variables in order to account for those important features of the RE sector, but spatial spillover effects was not the main objective to distillate from the data.

Carfora et al. (2021) used spatial econometric model, the SLX model, the SEM model and the SARAR model, to account for spatial spillover effects in the annual rate of RE sources investments in EU countries. Policy implementations were used as explanatory factors. Also, spatial spillover effects of the control variables were tested, containing economic factors like GDP and consumption of energy, substitute factors as the production of fossil and nuclear energy, environmental factors like greenhouse gas emissions. A positive spatial spillover effect is contributed by the writers to a knowledge spillover effect from countries with a comparative advantage to countries they export to. This is in line with the

Shahnazi & Shabani (2020) studied spatial spillover effects of renewable energy production in EU countries. They found a positive correlation between oil prices (substitution good) and renewable energy production. GDP exerted a u-shape pattern on Renewable Energy Production, explained by an initial increase in energy efficiency, followed by an increase in demand for clean energy in later stages of development. The paper examined spatial spillover effects by implementing a spatial system GMM model, which it found to be significant. This model estimates spatial spillover effects of the dependent variable, which is the size of production of renewable energy. They claim that knowledge spillovers and adopting similar policies of neighboring countries are the main driver of these spillover effects.

2.8 Spatial Spillovers in Policy Adoption

The reasoning behind investigation of spatial spillovers when considering policy implementation and its consequences is threefold, with policy diffusion as main concept. Social context plays a central role in the behavior of human individuals, and public administration literature has paid much attention to the social context in which public organizations operate (Cook et al., 2019). Policy diffusion literature examines phenomena behind adoptions of policies of one government in response to the adoption of policies of another government (Obinger et al., 2013).

First of all, governmental bodies might adopt policies based on cues from other entities, where organizational decision makers imitate others. This phenomenon is called memetic isomorphism (DiMaggio & Powell, 1983). In other words, an organizations decision making can partly be predicted by decisions of other (nearby) organizations. Research on this phenomenon points out that memetic isomorphism tends to take place between geographic units that are either in geographical proximity or feature the same revenue or demographic levels (Lundin et al., 2015). This is important because the specification of the Spatial Weight Matrix largely depends on the assumptions about underlining factors that cause spatial spillovers to occur.

Moreover, ideas or practices often spread through professional networks. Considering policy adaptation by governmental bodies, this is called normative isomorphism. Normative isomorphism also tends to take place between geographical proximate units of government, due to knowledge spillovers that are spatially constrained. Although information can be exchanged on a global scale, tacit knowledge is best exchanged when professionals interact face to face, which requires spatial proximity (Howells, 2002). Knowledge spillovers remain localized, making geography important in analyzing isomorphism and spatial spillover effects in policy adaptation. This again implies the use of a spatial weight matrix that indicates local ties between geographical units.

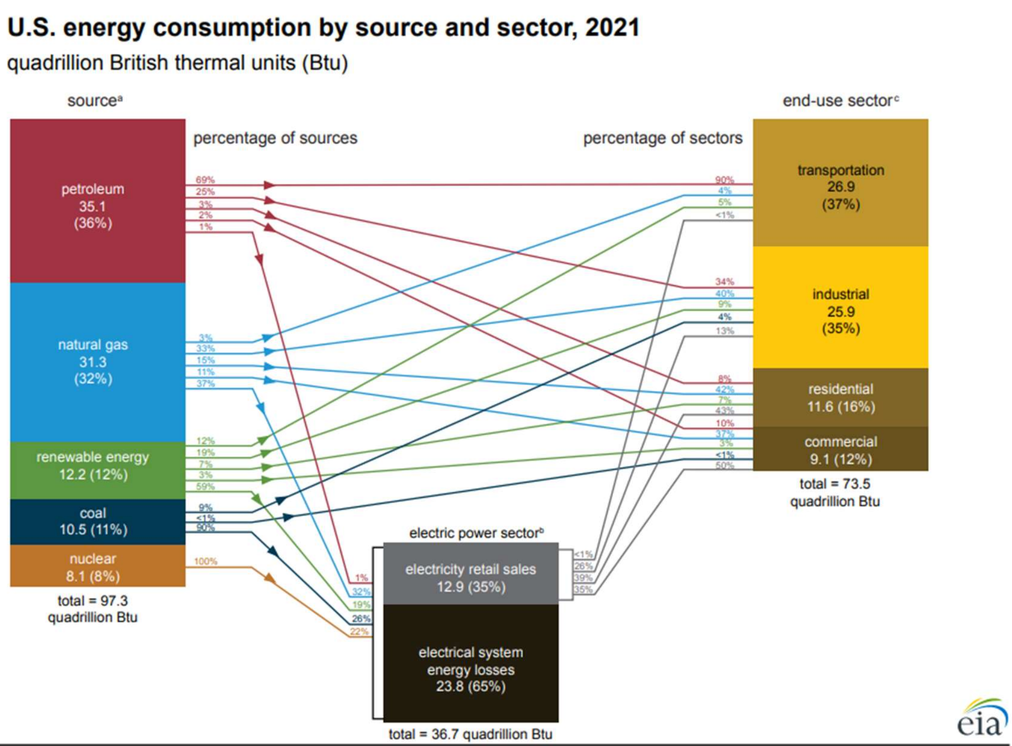
Thirdly, competition between governmental bodies occurs when they vie for the same clients or compete for scarce resources. Attracting firms or workers to their own local market could lead to a system in which organizations alter their policy implementation to ensure a competitive advantage over others (Cook et al., 2019). Governmental bodies that react to each other is often referred to as either a 'race to the bottom' or 'race to the top'. In environmental regulations, this might imply that competing states downgrade or relax their environmental their environmental standards in fear of losing economic investments (Koninsky, 2008). From a competition standpoint, the Renewable Energy Sector is thus a complex market in which it is uncertain how policy diffusion will take place between states. Spatial spillover effects of policies implemented could either be negative or positive when regarding competition. The same holds for the scale of these spillovers, as they could potentially be global in nature, meaning policy diffusion takes place on a global scale and spillovers reach all entities in the research area. As will be discussed later, the dynamic SDM model produces global spillover effects, and can be compared to local spillovers in the static models.

Following the theoretical underlying underpinnings discussed in this chapter, the following main hypotheses are constructed based on the two research questions as posed in the introduction. It is expected that implemented policies will benefit the regional competitiveness of the RE sector. In order to test this hypothesis as precise as possible, the different types of RE policies will be incorporated in the models, given the data that is obtainable. The way that implemented policies are quantified is discussed further in the methodology section. Also, the way of quantifying competitiveness on the basis of literature discussed is elaborated on in the methodology section. Furthermore, following the literature on policy diffusion, it is expected that spatial spillovers are present in policy adoption, which will exert an influence on RE competitiveness. Given the different mechanisms that could occur in policy diffusion, it is uncertain how these spatial spillovers will occur. Spatial spillovers of policies implemented are not yet investigated by exiting literature. This makes the research design of this paper unique, since it touches upon a research gap in the literature. It is interesting to investigate the way in which spatial spillovers occur in the policy landscape of RE, and how these effect RE competitiveness.

3. The energy market in the US

In this segment, the energy market of the US is analyzed. How does the market function, and who are the important players in this field? The understanding of the electricity market is necessary for this research in order to analyze the market and regional competitiveness thoroughly and holistically. One could make a distinction between primary and secondary energy, where primary energy sources entail fossil fuels like coal, natural gas and petroleum, nuclear energy, and renewable energy sources, while electricity is a secondary energy source. Because different sources of energy are measured in different physical units, British thermal units (Btu), a measure of heat energy, is used to compare multiple sources of energy. On a national level, quadrillion Btu's, or Quads are used to describe the consumption and production levels per sector (EIA, 2022B). The U.S. Energy Information Administration distinguishes five major sectors that use energy: Electric power sector, transportation sector, industrial sector, residential sector and commercial sector. In the figure below an overview of energy consumption and used energy sources in the U.S. in 2021 is shown (EIA, 2022A).

Figure 1, Energy consumption by source and sector, 2021 (source: EIA, 2022A).



It stands out that 59% of all energy produced from renewable sources is used by the electric power sector, in order to produce secondary energy in the form of electrical power. This is then sold to the other energy-consuming sectors. Furthermore, the enormous energy loss from electrical systems that are used for the generation, storage and transportation of energy in the electric power sector is quite noticeable.

It is necessary to understand the composition and regulation of the (renewable) energy market, to be able to examine competitiveness of renewables in different markets. Beside the market for fuel suppliers, which is completely private with companies compete to sell their products, the electricity provider market is rather complicated. Lastly, the type of energy market in place in a certain state affects the possibilities for renewable energy policies, as will be discussed later on.

3.1 Vertically integrated markets vs. Competitive Wholesale markets

The electric power industry used to be dominated by big utilities that decided upon all segments of electricity power, generation, transmission and distribution. These are called vertically integrated utilities (Joskow & Schmalensee, 1988). Since the energy market has a lot of characteristics that could lead to monopoly market structures, competitiveness in the electricity sector is prone to decrease under these circumstances. For instance, multiple grid systems to transport energy would not make sense, which gives the owner of the grid system monopolistic power. To ensure reliability of the electricity grid, single utility companies were given a monopoly within a geographic region, (EPA, 2022).

As societies reliability on electricity increased, confidence in those monopolistic, private utilities dropped. Because of various reasons, such as irrational tariff policies and inefficient system management, slowly the decomposed electricity market made its introduction (Karthikeyan et al., 2013). The Federal Energy Regulatory Commission (FERC) regulated transmission and wholesale of energy and transport, in order to ensure reliability. In response to this, transmission owners came together to form Independent System Operators (ISO's). These non-profit, private organizations got the approval of the FERC to oversee and regulate the transmission and distribution of electricity. The unbundling of the electricity market, or the separation of generation, transmission, storage and sales, slowly took place from the 1990s onward (FERC, 2021). According to Shahidehpour et al. (2017), the main practice that prevents competitiveness from happening in a market is market power in the form of monopolies. In the U.S. multiple states still operate under the vertically integrated conditions as discussed above.

3.2 Deregulated retail markets vs. Regulated retail markets

Within both types of markets as described above, states can decide whether to have a regulated or deregulated, competitive retail electricity market. In regulated markets, consumers cannot choose between different suppliers of electricity. Public Utility Commissions (PUCs) regulate these markets to ensure that monopolies do not drive up the price of electricity. In deregulated market, retailers compete to sell electricity to the end consumer. The retailers do not own the distribution- and transmission wires but are charged by the utilities for access on the grid (EPA, 2022). (De)regulation of electricity markets could potentially affect competitiveness within the Renewable Energy sector. Policy on Renewable Energy was found to more effective in fostering competitiveness in liberalized energy markets. It is therefore interesting to take the market design choice of states into account in the research (Nesta et al., 2014).

4. Methodology

4.1 Spatial Spillover effects

So far, the literature on Renewable Energy sources and the influence of policy implementation and other driving factors have been discussed. The literature slowly progressed over time, with researchers using more sophisticated models and better data. First, simple econometric models were used in order to estimate for the effect of presence or absence of different types of policies (Menz & Vachon, 2006; Fang et al., 2018). Then, time series were used in a panel dataset, in order to better understand the influence of these adopted policies on de deployment and relative size of the renewable energy sector over time (Lui et al., 2019; Carley et al., 2009; Kilinc-Ata, 2016; Przychodzen & Przychodzen, 2020). None of the studies mentioned above have entertained the possibility of spatial spillover effects of those implemented policies. Implemented policies could have an effect not only on the state itself, but on neighboring states as well. In the next segment the reasoning behind spatial econometric models is given.

Firstly, using standard Ordinary Least Squares models when dealing with samples that show dependence across units, whether time-related or cross-sectional dependence, often leads to biased and inconsistent estimates (Franzese & Hays, 2007). It is therefore beneficial to investigate the perks of spatial econometric methodologies when estimating the effects of policy on a certain variable. Spatial dependence, or spillover effects, can occur within the predictors, the outcomes, or the disturbance term (Elhorst, 2010). Considering this research, spatial dependence between the outcomes implies that competitiveness of one state endogenously affects competitiveness in another state. In contrast, spatial dependence in the predictors implies that either adopted policy or another explanatory variable in one state effects the competitiveness in the other. When unobserved variables which are not included in the model show spillover effects, they are included in the spatial spillovers of the disturbance term. Spillovers in the outcome are most commonly referred to in literature on public policy (Cook et al., 2019).

As discussed in the literature section, Shahnazi & Shabani (2020) claimed that endogenous spillover effects occur in the production of Renewable Energy in the EU. They lack to acknowledge that the spatial spillover effects with regards to renewable energy are exogenous, instead of endogenous. In other words, the independent variables such as implemented policies and knowledge spillovers are causing neighboring states to increase their renewable energy production, not the production itself. This fact is considered when choosing the right spatial econometric model for this research.

Another theoretical consideration in spatial econometric models is the specification of the spatial weight matrix (W). Depending on the types of spillover effects as mentioned above, extra variables are added to a standard OLS model in order to estimate for those effects. This N-by-N matrix represent the spatial connectivity of different units in the sample and is determined by the nature of the relationship between those units (Cook et al., 2019). Geographical proximity or ties of other natures can be chosen based on the theoretical underpinnings of the spatial dependence as selected by the research. Despite the fact that ''near things are more related than distant things'' (Tobler, 1970) is a widely accepted statement in (economic) geography, ''being near can take on different meanings in different situations'' (Tobler, 2004), which complicates the definition of proximity. Different W matrices give different empirical outcomes, which makes the specification of W extremely important (Leenders, 2002).

4.2 Data Selected

On the basis of the discussed economic geographical theories and competitiveness literature, A panel dataset of the Energy Information Administration with output measures of the renewable energy sector in every state is used, over a period of 21 years. The output of the sector is measured in Btu (Quads), a universal measure of heat energy, in order to compare for different types of energy. Because of the different theoretical underpinnings as discussed prior, two different dependent variables are selected to be included in the models. The annual production of renewable energy as a share of the total energy production per state is used as the dependent variable in the model. This way the market share of renewable energy in a given state in a given year is calculated, which gives an image of the market share of Renewable Energy within each state. I believe that this represents competitiveness, since it represents the ability to attract more firms to the state at hand over time, which equals a more competitive position of the local RE market. As discussed in the literature section, a relatively growing RE production implies that the centripetal forces are present, dominating the centrifugal forces, and agglomeration effects occur, making it in line with the underlining principles of NEG (Brakman et al., 2005). A bigger home market allows for new players to enter the market more easily, which increases regional competitiveness in a given state.

First, the dependent variables are chosen with the nature of competitiveness in mind. In contrast with Carley et al. (2009), who focused purely on output and chose absolute RE generation as their dependent variable, this paper investigates the competitiveness of the RE sector. This calls for the implementation of other variables. As analyzed in the literature section, the Diamond model implies that a cumulative presence of the four underlining conditions will create a competitive environment for firms to enter a regional market and stay competitive. As these four conditions, together with governmental structures, will create productivity. Hence, a second dependent variable is adopted in this research. The second dependent variable is the size of the market for Renewable energy by state as a percentage of the size of the Renewable energy market of the U.S. as a whole. This is calculated by dividing the Renewable Energy Production of a state in a certain year by the total Renewable Energy production of the U.S. in that same particular year. A bigger share of the RE sector in the home market means that the underlining conditions for competitiveness have improved, and productivity is increased which causes firms to stay in the market and the RE market to grow relative to the fossil-fueled energy market.

Another reasoning behind this is that a market share of a total market can reveal comparative advantage for some and comparative disadvantage for other. This is in line with the reasoning of Ricardo (1821) who first described the idea of comparative advantage at a country level. Since states in the U.S. have their own legislation, implemented policies and financial incentives, this particular approach of analyzing competitiveness can be used to compare states in a similar way.

In the table shown below, the dependent and explanatory variables selected and implemented in this research are described. Most variables have been log transformed, with the purpose of a more intuitive interpretation and the reduction of possible biased results. Log-log relationships can be interpreted as elasticities. Or how many percent changes the dependent variable if the independent variable changes with one percent. Variables that could not be transformed are either a dummy variable or variables that include the value zero. A transformation of the policy variables in order to make them suitable for a natural log transformation needs to be theoretically grounded, since it can influence the outcome of the predictors (Bellégo et al., 2022). The variables TotalRPS, NmbrFinInc and NmbrReg could not be altered without compromising the results, and therefore left as regular variables. A coefficient will be multiplied by 100, giving the percentage change when the independent variable increases with one unit.

Table 1, The list of selected (independent) variables in the models.

Variable	Var Name	Unit of measure	Source
Real GDP	lnRealGDP	Millions of chained 2012 dollars	Bureau of Economic Analysis
Unemployment Rate by state.	lnUnempR	Unemployment Rate.	Bureau of Labor Statistics
Size of the working population (18-64) by state by year.	lnWorkPop	Amount of people per state per year.	USA FACTS
Average Annual Price of all Petroleum products, all sectors, by state	lnPetPri	Dollars per Million Btu.	U.S. Energy Information Administration

(De)regulation of the electricity market by state (dummy variable)	DeReg	0 equals regulated and 1 equals deregulated. Markets that have been deregulated over time can change in value.	ElectricChoice
Total Renewable Portfolio Standard	TotalRPS	Percentage of total energy production by state by year.	Berkeley Lab
The number of financial incentives active in a certain year, by state.	NmbrFinInc	Number of incentives.	DSIRE
The number of regulatory policies active at a certain year, by state.	NmbrReg	Number of regulatory policies.	DSIRE
Share of Renewable Energy Sector by state (Dependent Variable 1)	lnStateShRes	Renewable Energy production per state by year, divided by the Total Energy production per state, by year, times 100. Both in Quadrillion Btu (Quads).	U.S. Energy Information Administration
States share of Total Renewable Energy Market (Dependent Variable 2)	lnTotalMarkSh	Renewable Energy production per state, by year, divided by the total Renewable Energy production for all states, by year, times 100. Both in Quadrillion Btu (Quads).	U.S. Energy Information Administration

4.3 Measures of Policy implemented

The main focus of this paper is to find a possible correlation between implemented policies and Renewable Energy Competitiveness. Several methods are regarded as suitable for this research question and processed in quantifiable variables to implement in regression models.

Market design

Following NEG and the notion of McWilliamson & Zachmann (2021) that market design choices matter for the economic geography of energy and dependent markets, and the notion of Nesta et al. (2014) that policies are more effective in liberalized energy markets, the market type of a state is implemented as a dummy variable. The value can be either 1, which is a deregulated market, or 0, which stands for a regulated market. Since the dataset is a panel dataset consisting of 49 states with observations from 21 different years, the value of this variable can change over time. Some states have deregulated the energy market during the timespan of the panel dataset.

H0: A deregulated markets will be more competitive in the RE sector than regulated markets.

Total RPS

As mentioned before, the most significant and frequently used policy tool is Renewable Portfolio Standard. Because this measure is easily quantifiable, a required percentage of energy produced must come from renewable sources, the percentages are implemented as a variable. Per year, the majority of states have implemented an RPS policy, which can alter in height and therefor change over time. States that have not implemented an RPS (yet) will get the value ‘0’

> *H0: A higher RPS will lead to states being more competitive in the RE sector. Total RPS will exert a positive spillover effect on neighboring states.*

Number of Financial Incentives & number of Regulatory Policies

The dataset of DSIRE consists of a large list of implemented policies, covering information about the type of policy, the state that the policy is implemented in and the starting or ending date of the policy at hand. This data is transformed into a quantifiable measure of the amount of two different types of policy implemented: Financial Incentives and Regulatory Policies. Menz & Vachon, who use dummy variables per policy implemented, chose a different approach. Following the notion of Lund (2009) that a learning curve matters in adopting the right policy mix, and further exploring the cumulative effect of implementing certain strands of policy, this paper quantifies policies implemented as follows: Financial incentives as discussed above such as grants, loans, feed-in tariffs, or tax benefits have been clustered into one variable. Regulatory policies like RPS, Net Metering or output-based environmental regulations are clustered in another variable. They both represent the amount of implemented policies at a certain time. The time-dimension of the panel dataset allows both variables to change over time, both positively and negatively.

> *H0: The number of financial incentives as well as the number of regulations in a state at a given time will increase competitiveness of that state. It will also spill over towards neighboring states, causing indirect effects.*

4.4 Control Variables

Besides the main focus of this paper on the influence of implemented policies on Renewable Energy Competitiveness, other factors are included in the models. With Porters Diamond model, New Economic Geography, and the papers discussed in mind, control variables are included that are likely to influence the dependent variables.

GDP or growth (Capital)

The GDP of a country represents to an extent the amount of capital present in a state. Since the initial costs of capital of Renewable Energy projects is relatively high, GDP could influence the capability of a state to establish a competitive Renewable Energy sector. Following Kilinc-Ata (2016) and Przychodzen & Przychodzen (2020), GDP is expected to have a positive influence on the relative market share of a states’ Renewable Energy sector, as well as the share of the total Renewable Energy sector of a state. However, as Shahnazi & Shabani (2020) mentioned, GDP growth might slow down competitiveness at first, since energy efficiency increases.

H0: In the long run, GDP will have a positive impact on a state's RE competitiveness.

Unemployment Rate

Following Fang et. Al (2018) and Przychodzen & Przychodzen (2020), the unemployment rate is added to the list of control variables as well. The labor-intensive nature of the sector, combined with the fact that the sector can help reduce unemployment, a positive relationship between unemployment and growing competitiveness is expected.

H0: Unemployment will have a positive impact on a state's RE competitiveness.

Labor Force

One of the pillars of competitiveness in the Diamond model is present factor conditions in a market. Just like capital, labor is important for a competitive market, especially in a labor-intensive market like the Renewable Energy sector, as Fang et al. (2018) suggested. Emphasizing the characteristics of the industry, the size of the labor force is expected to influence competitiveness positively. Furthermore, as NEG suggests, a greater labor force also implies a greater demand, one of the agglomeration forces. This could lead to dominant centripetal forces in an area, making economic activity in the region grow. Following this line of thinking, a bigger labor force is expected to increase the total market share of a states' Renewable Energy Sector, but not the share of Renewable energy of the total energy production in a state. In contrast to the positive direct effect of the labor force on a state's share of the RE sector, present labor in one state is expected to exert a negative effect on other states, since they compete for the same supply of labor, in line the reasoning by Cook et al. (2019), who discussed the competition for labor in policy literature. To estimate for these effects, the amount of people between the age of 18 and 64 is therefore included in the models.

H0: The labor force will have a positive direct impact on the total market share of a state's RE sector, but a negative indirect effect.

Price of Petroleum (substitute)

In line with the Diamond model by porter, which states that related industries could either enhance or disturb competitiveness, a substitution good is added to the model. The price of petroleum products is added to control for the attractiveness of substitute forms of energy, which can hinder competitiveness of the Renewable Sector. In line with Carfora et al. (2021) and Kilinc-Ata (2016), it is expected that a lower price of petroleum will increase Renewable Energy competitiveness.

H0: An increase in prices of Petroleum goods will have a positive effect on a state's RE competitiveness.

Table 2, Descriptive Statistics.

Variable	Mean	Std. Dev.	Min	Max
DeReg	0.3848397	0.486794	0	1
lnRealGDP	322601.4	390745.1	23016.8	2729226
lnUnempR	5.59932	2.023185	2.1	13.7
lnWorkPop	3877760	4270041	307642	
lnPetPri	18.67087	5.842563	7.03	30.9
TotalRPS	0.0441302	0.08119126	0	0.59
NmbrFinInc	43.82799	43.7553400	0	245
NmbrReg	12.31876	10.99706	0	85
lnStateShRES	36.79598	35.15703	0.14052	100
lnTotalMarkSh	2.03147	2.332325	0.0006688	15.49296

4.5 Models

As discussed prior, spatial spillovers in the renewable energy sector are an exogenous interaction effect and not endogenous. This entails that the competitiveness of a state in the RE sector depends on characteristics of neighboring states. Or, in other words, independent variable y of unit A affects independent variable y of unit B, which indirectly affects the dependent variable. This holds true because policy implementation could spill over towards other geographical units. The same holds true for working population, Unemployment Rate, GDP, and Petroleum prices.

The reasoning behind the spatial spillovers of the independent variables, or Wx, is outlined in the literature chapter, where policy diffusion causes spillover effects between spatial units. The implementation of a spatially lagged error term, or Wu, does not require economic or theoretical ratification. A spatially lagged error term implies that variables which are omitted from the model show spatial correlation. Another reason could be that unobserved shocks, economic crises or natural disasters, follow a spatial pattern (Elhorst, 2021). Hence, they are included in the models as selected for this research.

The Spatial Durbin Error Model for spatial panel data is chosen to estimate for spatial spillover effects of the independent variables and the error term. The basic formula is as follows:

$$lnTotalMarkSh_t = X_t\beta + WX_t\theta + \mu + \alpha_t\iota_N + u_t \qquad (1)$$

with

$$u_t = \lambda W u_t + \varepsilon_t \qquad (2)$$

Where $lnTotalMarkSh_t$ is the dependent variable, in this case the natural log of the share of a state's RE production in the total RE production for 48 states over a 21 year period. X are the explanatory variables as prescribed in the model, μ is an N x 1 vector of spatial fixed effects, α_t are the time period fixed effects with t=21, and u_t represents the error term and spatially correlated error term. The coefficients β, θ and λ represent the direct effect, indirect (spillover) effect and spatial correlation of the error term, respectively. In order to interpret the strength of the SDEM model, several other models are also used to compare for explanatory power. A standard OLS model with fixed effects is used to compare the SDEM model with a model without spatial spillover effects. An SLX models only includes spatially lagged independent variables and leaves the spatially lagged error term out. Furthermore, a General Nesting Model, which includes not only the spatially lagged independent variable and the spatially correlated error term, but also the spatial spillover effects within the dependent variable, is included in the analysis. Often the GNS model consists of a too many parameters and is therefore overparameterized, which means that the different interaction effects included in the model cannot be distinguished from each other (Burridge et al., 2016).

Because of the expected nature of spatial spillover effects in the dataset, which are believed to be local and subject to geographic proximity, a Binary Contiguity matrix W is created for the states of the U.S. This is an N-by-N row-normalized matrix whose elements are coded either 1 or 0, indicating if states share a common border or not (Elhorst, 2021). It is used to describe the spatial arrangement of the states of the U.S. Because of the nature of this matrix and research, Hawaii and Alaska are left out of the dataset, because they do not have common borders and thus do not fit in the matrix of binary contiguity.

4.6 Dynamics

The static models might not explain a large percentage of the variance of the dependent variables. This means that the selected explanatory variables do not predict a lot of the variance. In order to improve the static models, dynamics can be added to the model. The equation for the Dynamic SDM model with spatial and time fixed effects looks as follows:

$$lnTotalMarkSh_t = \tau TotalMarkSh_{t-1} + \rho WTotalMarkSh_t + \eta WTotalMarkSh_{t-1} + X_t\beta + WX_t\theta + \mu + \alpha_t\iota_N + u_t + \varepsilon \qquad (3)$$

where, other than the variables used in equation (1) and (2), $\rho WTotalMarkSh_t$ represents the spatial lag of the dependent variable, with coefficient ρ. $\eta WTotalMarkSh_{t-1}$ is the dynamic term representing the spatiotemporal lag of the dependent variable, with η as its coefficient. In contrast with the previous model, the dynamic SDM incorporates a spatial lag of the dependent variable. The inclusion of a spatially lagged dependent variable is necessary when estimating a dynamic model, and produces global other than local spillovers. This means that a change in any location in one of the independent variables will be transmitted towards all other locations, even if they a not connected according to the specification of the spatial weight matrix (Vega et al., 2015). In the case of this paper specifically, this would mean that policy diffusion, the process of mimicking or adopting policies from other states, is not geographically bounded, and will spill over through the entire U.S.

5. Results

5.1 OLS model and spatial models

In table 3 the results of spatial and non-spatial models estimating the regressors on the first dependent variable, namely Total Market Share are shown. To estimate for entity-specific individual characteristics that may or may not influence the explanatory variables in the model, that may impact or bias the results, the inclusion of fixed and or random effects needs to be tested for. The same holds for time-period fixed effects, where factors influence all states at a particular time period (Baltagi & Liu, 2008). In order to test for the inclusion of fixed or random effects, first a Breusch and Pagan Lagrangian Multiplier Test (1980) is performed. A standard OLS model is tested against a random-effects model (not shown), where the LM test is highly significant for both dependent variables, implying that the random-effects model is more suitable. Next, a Hausman test (1978) for random or fixed estimators is performed to compare the implication of fixed and random effects, which results in a significant outcome for TotalMarkSh and StateShRES, indicating fixed effects are more suitable than random effects.

Furthermore, it is important to investigate the strength of cross-sectional dependence in both TotalMarkSh and StateShRES. To do so, a CD-test (Pesaran, 2015) is performed to test for the degree of strong dependence in the panel dataset. In case of a significant outcome of a CD-test combined with an exponent alpha close to 1, the null-hypothesis that cross-sectional dependency is weak can be rejected. Spatial models can only be used when cross-sectional dependence is weak, otherwise standard OLS models suffices (Elhorst et al., 2021). In the case of TotalMarkSh, the p-value is insignificant and the alpha is less than 0.5, indicating weak cross-sectional dependence, meaning spatial models will be applied. The CD-test for StateShRES in contrast, shows that strong cross-sectional dependence is present in the data. In spite the fact that OLS models are sufficient for StateShRES, economic theory as discussed prior suggest that estimating for spatial spillover effect is accounted for. A Dynamic Spatial Durbin model with cross-sectional averages can be used to account for spatial spillover effects within the regressors of StateShRES. The outcomes of all tests discussed above are found in table 3.

Table 3, Tests for preferred model specification.

	TotalMarkSh	**StateShRES**
LM-test	5318.77	8474.72
	(0.000)	(0.000)
Hausman (Prob>Chi2)	(0.000)	(0.000)
CD-test	-1.464	56.895
	(0.143)	(0.000)
Alpha	-0.4173593	0.920059

Significance levels in the parentheses (p<0.01, ** p<0.05)*

Before analyzing the results of the models, it must be stated that the for one of the independent variables, lnStateShRES, the outcomes of the models did not show any significant results, and coefficients varied significantly. The depicted models and variables cannot be used to make reasonable conclusions about the share of Renewable Energy in the total energy mix per state. The models are not robust and therefore reasonable analysis of these outcomes is not possible. The Dynamic Spatial Durbin model with cross-sectional averages as therefor left out of this paper. From this point, the outcomes of the models with the other independent variable, lnTotalMarkSh, are discussed. In table 4 the correlations table of the dataset is displayed.

Table 4, Correlation Table.

	LnStateShRES	**lnTotalMar~h**	**DeReg**	**lnRealGDP**	**lnUnempR**	**lnWorkPop**	**lnPetPri**	**TotalRPS**	**NmbrFinInc**
LnStateShRES	1.0000								
lnTotalMar~h	0.0851*	1.0000							
DeReg	0.1507*	-0.1709*	1.0000						
lnRealGDP	0.0040	0.4687*	0.2763*	1.0000					
lnUnempR	0.0273	-0.0019	0.1147*	0.2491*	1.0000				
lnWorkPop	-0.0355	0.5696*	0.1926*	0.9722*	0.2686*	1.0000			
lnPetPri	0.1275*	-0.0127	0.0347	0.0239	0.2496*	-0.0153	1.0000		
TotalRPS	0.2463*	-0.0370	0.3548*	0.0449	0.0217	-0.0009	0.2210*	1.0000	
NmbrFinInc	0.2207*	0.3781*	0.1274*	0.4992*	0.1919*	0.4612*	0.4632*	0.3668*	1.0000
NmbrReg	0.1072*	0.2421*	0.2551*	0.4952*	0.1840*	0.4533*	0.3707*	0.4447*	0.7844*

** Significance level = 0.05.*

In table 5 the results of both the non-spatial OLS model with time fixed effects as three spatial models with space- and time-fixed effects are shown. The performance of the models will be assessed through Maximum Likelihood estimation and the R2 sign. Comparing the Log Likelihood estimator, the performance of the SDEM model and the GNS model is superior to the OLS model and the SLX model, with similar explanatory power. The R2 also increased as spatial lags are implemented, which means the SDEM model and the GNS model account for more of the variance present in the dataset than the non-spatial OLS model.

Table 5, The OLS model and three Spatial Econometrics models.

TotalMarkSh	**OLS with time-fixed effects**	**SLX with time-fixed effects**	**SDEM with space- and time-fixed effects**	**GNS model with space- and time fixed effects**
DeReg	-0.2244711 (-0.291)	-.4298254 (0.041)	-.3173717 (0.102)	-.2943847 (0.099)

lnRealGDP	1.366314 (0.000)*	1.223081 (0.000)*	1.259391 (0.000)*	1.064568 (0.000)*
lnUnEmpR	0.0994975 (0.024)**	.2145376 (0.032)**	.1781386 (0.041)**	.2060826 (0.017)**
lnWorkPop	0.0631426 (0.880)	1.732415 (0.000)*	1.750299 (0.000)*	2.34627 (0.000)*
lnPetPri	-0.1390486 (0.003)*	0.0789241 (0.836)	-0.1180708 (0.702)	0.275417 (0.410)
TotalRPS	-0.4267414 (0.073)	-0.3653056 (0.215)	-0.2458348 (0.330)	-0.2743279 (0.278)
NmbrFinInc	-0.0020161 (0.004)*	-0.0034719 (0.000)*	-0.0035968 (0.000)*	-0.0037744 (0.000)*
NmbrReg	0.0054244 (0.123)	0.0136637 (0.000)*	0.0166897 (0.000)*	0.0169426 (0.000)
W x DeReg		-0.4279498 (0.424)	-0.3380903 (0.524)	-0.0783216 (0.866)
W x lnRealGDP		1.841904 (0.000)*	2.877205 (0.000)*	2.438076 (0.000)*
W x lnUnEmpR		-0.030587 (0.776)	-.1573356 (0.373)	-0.1141499 (0.444)
W x lnWorkPop		-6.683613 (0.000)*	-6.865491 (0.000)*	-7.22486 (0.000)*
W x lnPetPri		-0.2542898 (0.510)	-2.343122 (0.000)*	-1.922529 (0.000)*
W x TotalRPS		-2.01877 (0.000)*	-0.5957105 (0.269)	-0.7033541 (0.096)
W x NmbrFinInc		0.002801 (0.046)**	0.0050991 (0.003)*	0.0053637 (0.000)*
W x NmbrReg		0.0065956 (0.409)	0.010396 (0.206)	0.0086006 (0.232)
W x u			0.4661423 (0.000)*	0.0011616 (0.992)
W x Y				0.4686288 (0.000)*
R2	0.2352	0.1024	0.3503	0.3379
Log-Likelihood	-343.3909	-304.4805	-193.6920	-187.3845

Significance levels in the parentheses (p<0.01, ** p<0.05)*

Direct effects

When reviewing the direct effects of the models shown above, the policy variables show a divided pattern, and differ from the expectation as set beforehand. TotalRPS shows a negative sign which is highly insignificant. The number of financial incentives implemented at a certain time have a very small negative effect, which is significant, and in contrast with the expectations. The hypothesis stated that the number of financial incentives implemented would have a positive effect on TotalMarkSh. This is not the case and the hypothesis can be rejected, meaning that there could not be found any evidence for the benefits an increase the amount of implemented financial incentives for an increase in competitiveness in the RE sector. The number of regulations do show a small positive sign, which is only significant in the SLX model and the SDEM model. An increase in the amount of regulations does have a positive effect on TotalMarkSh in the dataset, however small. DeReg, or the regulation of the market, does not show any significant correlation with TotalMarkSh. In the dataset, the market design does not influence the competitiveness in the RE sector.

The control variables do show some significant results. It can be noticed that GDP, the unemployment rate and the labor force exert the expected effect on a state's share of the total RE market. All three are positive and significant in all models, except for the labor force in the OLS model. The price of petroleum does not show a clear pattern, as the sign and significance levels differ across the model.

Indirect effects

First the indirect effects of the different policy variables is discussed. As mentioned before, it is expected that implemented policies will exert an indirect effect on TotalMarkSh, meaning that spatial spillovers are present in the dataset and policy diffusion exists. With the different mechanisms in policy diffusion in mind, the sign of the coefficients of the indirect effects is not certain. Policy diffusion to a certain extend can be backed up by the results in table 5. The Renewable Portfolio Standard (TotalRPS) and the number of regulations (NmbrReg) do not spill over towards other states, and therefore do not increase competitiveness in neighboring states. The number of financial incentives in a certain state by year do have a positive effect on TotalMarkSh of neighboring states. The positive sign of 0.0050991 in the SDEM model reflects a 0.5 percent increase of the market share if a neighboring state implements 1 extra financial incentive. Apparently, a cumulative effect of the financial incentives policy landscape of one state gives the RE competitiveness of neighboring states a boost. This is interesting, since the number of financial incentives has a negative effect on a state's own RE competitiveness.

The indirect effect of GDP, the impact a positive change of a states GDP will have on other states, is very significant and shows a strong positive sign. Apparently, surrounding states profit from being close to an economically thriving state, as spatial spillovers occur. It could be explained by the present capital in and around states with a higher GDP. This makes it more feasible for firms in the RE sector to start RE initiatives and further strengthen the competitive position of the local RE market. What stands out is the fact that the labor force shows a very strong negative indirect effect that is significant. Apparently, if a labor force is big in one state, other states get hindered in their RE competitiveness. When considering the notion of NEG that centripetal forces like the home market effect create economic centers and economic peripheries, it is logical to conclude that competition amongst states for the labor-intensive sector of RE is occurring.

The last finding that stands out in table 5 is the fact that the spatially lagged dependent variable included in the GNS model is positive and significant. The coefficient of 0.4686288 represents an elasticity, meaning that an increase of a neighboring state's share of the RE market of 1 percent, will increase a state's share of the RE market with 0.47 percent. This is an interesting finding, since it suggests that endogenous factors of the RE market show spillover effects to neighboring states, in contrast with the expectations as set beforehand that the spatial spillover effects are exogenous.

5.2 Dynamic model

The results of the dynamic model are shown in table 6. The Log-likelihood measure is far greater than the static models, indicating that the implementation of a time lagged variable is suiting the data. Clearly policy effectiveness takes time before it can influence RE competitiveness in the form of relative market shares. However, the selected independent variables do not account for a lot of the variance in the model. Except for the labor force, where the same results are significant for the variable lnWorkPop as in the static model, with a positive short-run direct effect and a negative short-run indirect effect. In contrast with the expected short-term negative effects of GDP growth on competitiveness, due to an increase in energy efficiency, GDP exerts a positive effect on lnTotalMarkSh in the short- and long-run.

Table 6, Dynamic SDM model with spatial and time fixed-effects.

lnTotalMarkSh	***Short-run direct effects***	***Long-run direct effects***	***Short-run indirect effects***	***Log-run indirect effects***
DeReg	-0.0489627 (0.766)	-0.9668025 (0.980)	-0.3267953 (0.467)	-4.44968 (0.955)
lnRealGDP	0.0306165 (0.809)	0.6190528 (0.970)	0.298062 (0.438)	-2.285434 (0.972)
lnUnempR	0.0329564 (0.497)	0.1335354 (0.989)	0.0081638 (0.937)	-1.733274 (0.966)
lnWorkPop	1.073866 (0.000)*	7.884855 (0.636)	-1.520849 (0.012)*	-3.492205 (0.995)
lnPetPri	-0.0998233 (0.596)	0.8963909 (0.975)	0.2077173 (0.545)	6.099062 (0.963)
TotalRPS	0.1600549 (0.229)	1.454411 (0.653)	-0.1680492 (0.560)	-0.2765437 (0.998)
NmbrFinInc	-0.0012839 (0.001)*	-0.0113707 (0.889)	0.0008459 (0.434)	-0.1395036 (0.965)
NmbrReg	0.0036787 (0.054)	0.0939339 (0.934)	0.0078186 (0.135)	2.600783 (0.961)
W x Y		0.8748008 (0.000)*	0.212651 (0.000)*	-0.1609632 (0.002)*
R2 **Log-likelihood**	0.8582 341.4655			

Significance levels in the parentheses (p<0.01, ** p<0.05)*

The first finding from table 6 is the fact that no evidence is found to support the hypothesis that implemented policies will have a positive on RE competitiveness. TotalRPS, DeReg and NmbrReg all have negative coefficients, and NmbrFin has a negative significant effect on TotalMarkSh. This is in contrast with the theories as discussed, and counterargues the prediction that the number of policies can alter the economics of RE initiatives to foster competitiveness. This holds true for the short-term and the long-term effects in the dynamic model. Furthermore, the indirect effects of all policy-related variables mentioned above are also not significant. An increase in RE competitiveness as a consequence of policy diffusion is also not found in this model and the hypothesis that was stated in the beginning can be rejected.

The following findings also contradict the hypotheses of this paper, but are interesting to mention, since they explain the variance in the outcomes, and thus are an explanation for an increasing RE competitiveness. The row of W x Y coefficients represents the endogenous direct and indirect effects within lnTotalMarkSh. The time-lagged independent variable, or the long-term direct effects, are significant and represent a positive correlation. The indirect effects of lnTotalMarkSh are positive in the short-run, but negative in the long-run. Endogenous spillover effects occur in both positive and negative ways. The RE market share of a state positively influences other states at first, with an elasticity of 0.21. However, the dynamic model tells that spatial spillovers turn towards a negative effect in the long-run, with an elasticity of -0.16. In other words, an increase in a state's market share of the total RE market of 1 percent will increase neighboring states their market share by 0.21 percent, but in the long-run it will decrease it by 0.16 percent. This might not seem like a large number at first, but it definitely entails a significant indirect effect.

6. Conclusion

In this paper the effects of the policy landscape of states in the U.S. with regards to Renewable Energy on the competitiveness of the local RE market and surrounding markets are analyzed, together with a set of selected socio-economic factors that, backed up by economic geographical theories and existing literature, possibly influence competitiveness likewise. Furthermore, spatial- and temporal lags of these effects are estimated in a set of models that include spatial interaction effects and time-lagged variables.

The main focus of this paper is the correlation between policy implementation and competitiveness of the local RE sector. The exogenous variables that represent the implemented policies in a state and over time do not exert all initially expected direct and indirect effects on RE competitiveness. Direct effects are negative or insignificant, which is in contrast with the goal of policymakers to alter the economics of RE initiatives and make them more feasible. However, indirect effects can be found in the models used, as the number of financial incentives has a positive effect on neighboring states. Based on policy literature and common sense, this could mean that neighboring states learn from and improve existing financial structures in surrounding governmental bodies. This needs further investigation, as it is interesting to see how this process works. Policymakers of regions that lag behind in being competitive in the RE sector should not focus on the implementation of more financial incentives, since this does not lead to a better competitive position for the regional RE sector, but they should learn from existing incentives in other states. The notion mentioned in this paper that cumulative benefits of increasing the amount of RE policies will happen because of a learning curve, can be dismissed. In contrast, improving the quality of financial incentives by learning from other states should be the focus for policymakers.

The second finding that stands out when analyzing direct effects is the importance of a strong home market in order to create a competitive environment for the RE sector. Labeled by NEG as centripetal forces or agglomeration effects, both an increasing GDP and a strong labor market are improving the competitiveness of the local RE market, representing both locally present capital and labor. The characteristics of RE projects and initiatives, high initial costs of capital due to a long return to investment and labor-intensity of the industry, do in fact reflect the importance of these variables.

The indirect effects of GDP and the labor force found in this research are an interesting feature of the RE market, since they further strengthen these notions. The positive effects of GDP, present local capital, spills over to neighboring states, while competition for labor has a negative spillover to the ability of neighboring states to be competitive. As a consequence, the weak or non-existing correlations between policy and competitiveness of the RE sector can be explained by the fact that the qualities of a home market are dominant factors when it comes to the industry of Renewables. Undoubtedly policy landscapes have an important effect on the transition towards a cleaner energy sector in general, however they are subject to existing factors that depict the very fundamental foundations for a competitive RE sector. Further research is of great importance in order to investigate these interplays between policies and regional characteristics of the RE market. Also, policymakers could focus on strengthening the home market, by encouraging workers to come to their region and counteract the negative spillovers of competition for labor. Competing for the best workers is found to be influential in competitiveness within the RE sector. Creating a better environment for workers to come to a region, by education or improving labor conditions, may benefit RE competitiveness. These effects are indirect, but could benefit the RE market in the long-run.

Another finding that stands out and differs from the expectations as set beforehand, is the presence of endogenous interaction effects between states in lnTotalMarkSh. Both the static GNS model and the Dynamic SDM model estimate endogenous spillover effects that are significant and positive, where the dynamic model finds a negative spillover effect in the long term. This sets the stage for further research on the processes behind competitiveness of the RE sector. According to the results in this paper, endogenous characteristics of local RE markets cause spatial interaction effects to occur. A possible explanation for these endogenous effects could be the stickiness of present geography of Renewable energy. The narrative as discussed at the beginning of this paper about the energy transitions' influence on a changing economic geography and landscape of economic activity, and its dependence on 'sticky' characteristics of the energy market, can be used to shed light on this finding of endogenous factors in the RE sector. Apparently, neighboring states profit from thriving RE markets in the short term, but suffer from them in the long term. In the early stages of development, less successful states ride along on the success of RE agglomerations, but as time progresses they lose the competitive advantages to the established power houses of RE development. Could it be that endogenous characteristics of the RE market cause the spatial distribution of competition to stick to existing spatial patterns? This finding is very fascinating and asks for more in-depth analysis of the processes behind Renewables and their economic geography.

7. Reflection

The research design as adopted by this paper is very insightful, and sheds light on processes behind competitiveness in the RE sector, but knows its limitations. Firstly, the chosen variables for policy implementations are quantitative in nature. The number of financial incentives and regulations do say something about the quality of the policy landscape of a given state, but the quality of the policies themselves are crucial for success. A small number of perfectly effective policies that target the economic hurdles of RE initiatives as discussed could outperform a larger number of less effective policies or incentives. The vast majority of quantitative analysis in Renewable Energy policy literature deals with this problem. However, qualitative research alone cannot measure outcomes of the competitiveness of the RE sector. Hence, the right way to classify a dataset and adopt variables in quantitative research is of major importance in increasing understanding of the dynamics in the RE market. Which is in itself crucial in fostering the transition towards fossil-free, clean energy as mentioned at the very beginning of this paper. Future research should focus on the quantification of quality of policies implemented to foster RE competitiveness. Qualitative research could help doing so, by further increasing knowledge on the best possible way to implement RE policies so that regional RE markets can grow. This interplay between qualitative research and quantitative estimation of effectiveness is of major importance to understand dynamics an industry where policies are necessary to construct a competitive environment. In the Renewable Energy sector, this is still the case, since free market environments still favor fossil-fueled energy markets, as stated in the introduction.

Despite the limitations of the data used in this paper, new light has been shed on the processes behind policy implementation and the effects on regional competitiveness in the RE sector. Endogenous spillover effects in the market share of a state in the total RE market are found to be significant and encourage further research to investigate how these endogenous effects occur, and how they can be measured more precisely. This paper helped to set the stage for further research to increase understanding of the RE market. As mentioned in the conclusion,

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