UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree Project in Economics

Willingness to Wind

-A panel data study of public policies and municipal factors determining the deployment of wind power in Swedish municipalities

Emilia Hygstedt and Ulrika Kjellström

Supervisor: Fredrik Carlsson
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Graduate School

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Abstract

In 2009 the Swedish government adopted a national planning goal of 30 TWh wind power by 2020, implying a large expansion is needed from the current level of 7 TWh. The municipal territorial planning monopoly implies that the municipalities have a high degree of independence in the decision of installing wind power. This has led to large differences between municipalities; some have a large amount of installed wind power while others have none. This thesis uses panel data from the period 2003-2011, with the aim of analyzing the effect of national policy instruments, market conditions and municipal specific factors on the deployment of wind power in Swedish municipalities. We find a significant effect off two policy instruments, the Green Certificate System and the EU´s Emission Trading Scheme. The results show that more wind power is installed in municipalities with a left wing political majority and a successful tourism industry, but appears unrelated to other municipal factors, such as wind capacity. Our findings suggest that social conditions affect the deployment of wind power, not favorable physical conditions.

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Master of Science in Economics

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Göteborg, May 14, 2011.

Emilia Hygstedt & Ulrika Kjellström

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1. Introduction

In a time with climate change and depletion of finite resources, many have turned their attention to the use of renewable energy resources, wind power being one of them. Wind is free and it is always windy somewhere, which makes it an attractive resource to explore. In 2009 the Swedish parliament accepted a government proposal of a planning framework for 30 TWh wind power by 2020, which is far away from the present installed capacity, which just reached over 7 TWh in 2012 (Svensk vindenergi, 2013). The increase of wind power has been substantial since the beginning of the 1990s, when investments in wind power started to take off due to a number of introduced policy incentives. However, there are significant differences between municipalities when it comes to the amount of installed wind power capacity. In 2011, 45.5 percent of Swedish municipalities had zero installed capacity.

Qualitative research regarding wind power such as Khan (2003) highlights the fact that Swedish municipalities have a high degree of independence when it comes to the planning process regarding wind power. This has resulted in significant municipal influence over the siting of wind turbines, and large differences in the deployment of wind power. Söderholm et al. (2005) argues that despite general positive attitudes towards wind power in Sweden, on the local level however, opposition due to noise and visual impacts is common. The large differences in the deployment of wind power in Swedish municipalities are also addressed in a study by Waldo et al. (2012). This study is the first in our knowledge to empirically address the issue in a local context, where the role of physical and social municipal factors are analyzed, using a cross section of all Swedish municipalities. The result of the study shows that municipal factors have a role in driving the deployment of wind power in Swedish municipalities. Waldo et al. (2012) finds a significant effect of social factors such as population growth and tourism, whereas wind conditions do not have any significant effect.

The purpose of this paper is to extend the analysis by Waldo et al. (2012). We will use a panel consisting of all Swedish municipalities during the time period 2003-2011. This approach enables us to analyze both municipal specific conditions and the possible effect of policy instruments that directly or indirectly targets the deployment of wind power.

The analysis is performed with the use of panel data techniques, and the random effects tobit model is applied. The quantitative empirical work regarding the effect of market factors and policies promoting renewable energy have mostly focused on Europe and the US. Menz and

Vachon (2006) who analyzes policies promoting wind power in the US and Carley (2009) focuses on the determinants of the contribution of renewables to energy supply in the US. Marques et al. (2010, 2012) analyze the drivers promoting renewable energy in Europe. For the case of Sweden the empirical literature is scarce, and we will mainly draw from the research by Waldo et al. (2012). Data on the amount of installed wind power on municipality level between the years until 2003-2012 is our dependent variable and the explanatory variables are grouped into three categories; (i) political factors and market conditions, (ii) physical municipal specific factors and (iii) social municipal factors. The contribution of this thesis is a deeper understanding of what effects the deployment of wind power, since we explore the variation both between municipalities and over time. The time dimension also enables the analysis of market conditions and public policies that impacts the profitability of investments in wind power.

The results from the analysis show that two policy instruments; EU´s Emission Trading Scheme and the Green Certificate System, as well as the market conditions; electricity price and the development of technology have a positive impact on the deployment of wind power, which is in line with previous studies by Marques et al. (2012), Carley (2009) and Menz and Vachon (2006). The social municipal specific factors; tourism and having a left wing political majority also have a positive and significant effect on the deployment of wind power on a municipal level, but the physical municipal specific factors such as wind capacity does not appear to have an effect on the deployment of wind power, which is in line with the findings of Waldo et al. (2012).

The thesis is organized as follows: section 2. *Background* provides an insight into the function of the electricity market, the development of wind power in Sweden, the policies designed to promote wind power, the permit process and public attitudes towards wind power. Section *3. Theoretical framework*, outlines why there is a need for public intervention in supporting wind power, the economic theory behind different types of policies, the effectiveness of the policy instruments, as well as the issues related to implementation. In section *4. Determinants of wind power deployment in Sweden*, the determinants of wind power, as suggested by previous literature, are discussed, as well as previous findings, our hypotheses and descriptive statistics. In section *5. Empirical strategy*, the econometric approach is presented. *Section 6. Results*, the results from the econometric analysis is presented and in section *7. Discussion and conclusion*, we will discuss and conclude our findings.

2. Background

2.1 The electricity market

In the 1950s, oil was the largest energy source in Sweden. Until the late 1960s the electrification in Sweden relied on the expansion of hydropower, which today accounts for almost half of the electricity production. To save the remaining unexploited rivers in Sweden, the focus turned to nuclear power which was greatly expanded during 1973-1985, which in turn also caused the use of oil to drop substantially (Nilsson et al., 2004).

Table 1 below shows the Swedish electricity supply during the time period 1993-2011. The share supplied by hydropower and nuclear power dominates production. The production share from other energy sources varies depending on water supply and the productivity of the nuclear power plants (Swedish Energy Authority, 2012a). As can be seen in the table 1, the supply of wind power to the total electricity supply has increased significantly, but wind power only accounts for 4 percent share of total energy supply in 2011.

Table 1 The Swedish electricity supply by type of production (TWh)

Electric	**1993**		**1999**		**2005**		**2011**	
Power sources	TWh	%	TWh	%	TWh	%	TWh	%
Hydro power	73.8	49.4	70.9	44.5	72	42.4	66.7	41.7
Nuclear power	58.8	39.4	70.2	44.1	69.8	41.2	58	36.3
Thermal power	8.8	5.9	9.4	5.9	12.3	7.3	16.8	10.5
Wind power	0.1	0.07	0.36	0.2	0.9	0.5	6.1	3.8
Import	7.9	5.3	8.5	5.3	14.6	8.6	12.5	7.7
Total power supply	149.2	100	159.2	100	169.6	100	160	100

Source: Statistics Sweden (2013a)

Since the deregulation of the Swedish electricity market in 1996, consumers are free to choose their supplier. The electricity price is determined on the common Nordic electricity stock exchange “Nord Pool”. The price is an equilibrium price, decided by the last accepted selling bid. The last accepted selling bid equals the marginal production cost of the most expensive production facility needed to meet demand. All actors offering selling bids below the equilibrium price is allowed to sell the offered amount of electricity to the marginal price, and actors offering to sell for a price higher than the equilibrium price are not allowed to sell. This implies that all available electricity production compete on equal terms and is valued equally, independent of production technology. The supply on the Nordic wholesale power market is largely decided by the amount of hydropower, which in turn is decided by the amount of rainfall. During years with little rain the electricity price will be high. How high is dependent on the marginal cost of the electricity production used in its place. Other forms of electricity production, in table 1 denoted thermal power, mainly come from cogeneration plants, in general from biomass-based cogeneration and industrial back pressure production. The Nordic countries exchange power mainly with Germany, but also Poland and Russia. Mostly, Nordic countries are net-exporters, but certain years, such as 1996 and 2003, there was a net-import from Germany. Oil and coal condensing power production in Sweden is generally very small, in Finland, Denmark, Poland and Germany however, fossil-based thermal power is the largest single production technology. In a common price area, this means that the marginal electricity, i.e. the last produced MWh needed to meet demand, can be generated from fossil based thermal power. This in turn implies that the price on electricity in Sweden will be affected by prices for oil, coal and natural gas (Swedish Energy Authority, 2006).

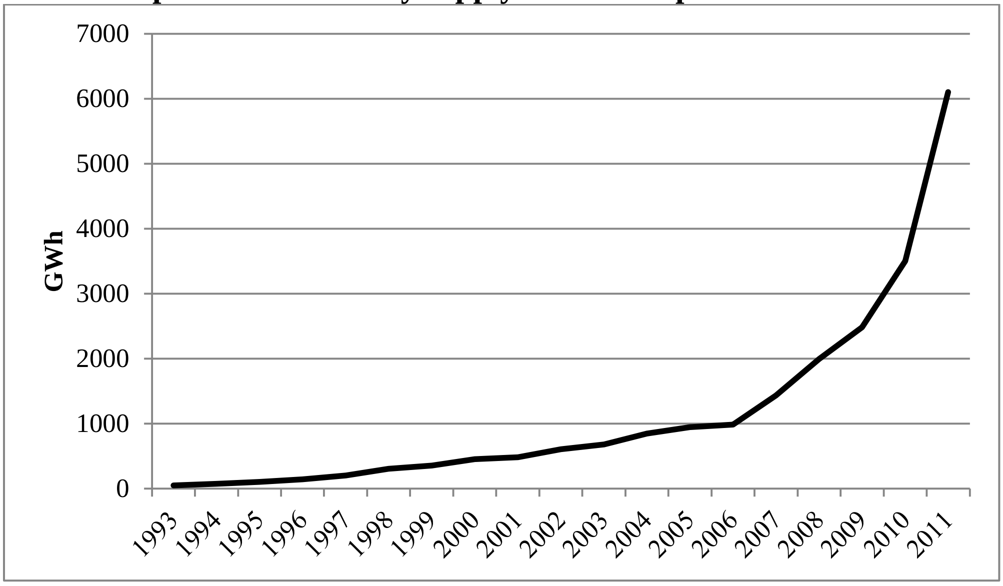
2.2 The development of wind power in Sweden

The Swedish electricity system is well suited for wind power. A large share of the electricity comes from hydropower and wind power is an ideal supplement to hydropower. When the wind velocity is high, wind power can be used, whereas hydropower can be stored and used when needed. Several studies show that the capacity in Sweden is large, from 30 to estimates of 40-50 TWh (Wizelius, 2007; Åstrand and Neij, 2006).

Despite the favorable conditions for the use of wind power in Sweden, the development has been modest compared to other countries with similar conditions, such as Denmark, Germany and Spain. The difference in the development between the countries cannot be attributed to a weaker design of implemented policies, one difference is however that the Swedish policy instrument have been considered uncertain and erratic (see section 2.4) (Söderholm et al., 2005).

Figure 1 shows the development of electricity supplied by wind power during the time period 1993-2011. The increase has been substantial since the beginning of the 1990s, when investments in wind power started to take off due to a number of new policy incentives. The number of wind turbines has continued to increase every year since 1990 (Swedish Energy Authority, 2012b). During the 1990s, mostly individual turbines were built, whereas today, large parks, with several turbines are planned and built. The average capacity of the wind turbines built has steadily increased since the early 1990s (Wizelius, 2007).

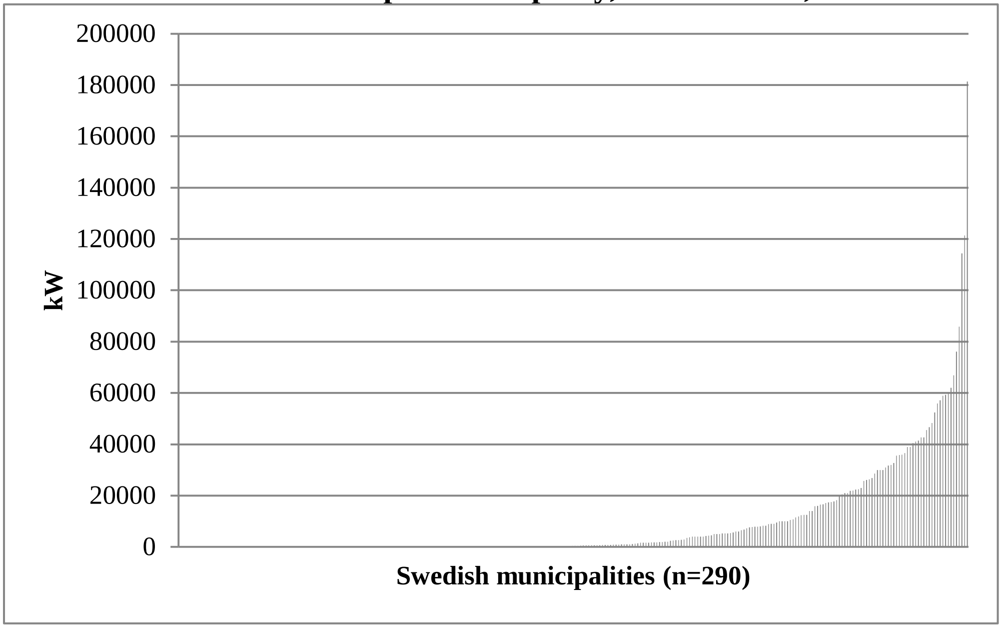
Figure 1
The development of electricity supply from wind power



Source: Statistics Sweden (2013)

The average installed capacity per municipality is 10 231 kW in 2012, but there are significant differences between municipalities when it comes to the amount of installed capacity. This can be seen figure 2 below, where the installed capacity in Swedish municipalities are organized from the smallest to largest installed capacity of wind power.

Figure 2
Total installed effect in kW per municipality, December 33, 2011



Source: Swedish Energy Authority (2013a)

During 2003-2011, the majority of the municipalities had zero installed capacity, although that fraction has decreased from 2003 to 2011. In 2003, 69.3 percent of the Swedish municipalities had zero installed capacity, whereas the same number was 45.5 percent in 2011. The municipalities that distinguish themselves through big spikes in the figure 2 are Gotland, Strömsund and Malmö (Swedish Energy Authority, 2013a).

2.4 Swedish energy policy and wind power

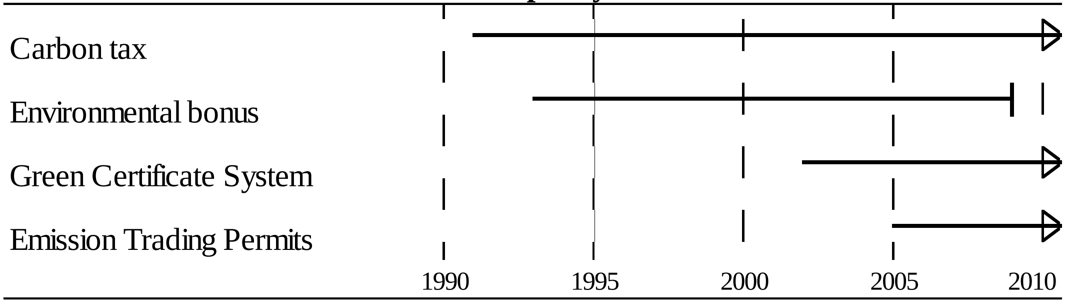
After the oil crises in 1970 the promotion of renewable energy in Swedish energy policy started to gain momentum. During the 1970s the energy policies mostly focused on reducing the oil dependency. In the 1980s the decision to phase out nuclear power was made and policies were mainly concerned with energy sources that could compensate for a reduction in nuclear power. Since the 1990s focus has been on securing short- and long term energy supply that is internationally competitive and increasing the share of energy generated from renewable sources, with the aim of achieving a sustainable energy system (Åstrand and Neij, 2006).

2.4.1 Policy instruments affecting wind power deployment

Despite the demonstrated interest in the development of wind power since the 1970s, the energy policy objectives have been weak. During 1970-1990, research funding for the development of wind power was introduced, but gave little results in the expansion of wind power. In the 1990s policies aimed directly at an increase of wind power deployment was implemented, such as an investment support subsidy and the environmental bonus. In 2002 the Swedish parliament accepted a planning target of 10 TWh in 2015, which can be considered trend shift towards a higher ambition level regarding the wind power deployment (Michanek and Söderholm, 2006).

Below follows a presentation of the design of the policy instruments that has affected the wind power deployment in Sweden, both directly and indirectly, during the period of interest. The time of implementation and duration of the policies can be seen in figure 3 below.

Figure 3
Years of introduction and duration of policy instruments



2.5.1The environmental bonus

With the sole purpose of supporting wind power, the environmental bonus was introduced in 1994. The producers of wind power were given a subsidy for every produced kWh, equivalent to the energy tax for households. The procedure was regulated by a contract between the producers and the energy suppliers, where the households paid the energy tax to the energy supplier, which in turn paid it forward to the producers of wind energy (Åstrand and Neij, 2003).

The environmental bonus was a short term policy, and the regulations and levels were changed during the course of the program. Originally the environmental bonus was supposed to be operating until 2000, but the European Commission agreed to extend it during the transition to the Green Certificate System (Åstrand and Neij, 2003). After the introduction of the Green Certificate System in 2003 it was gradually phased out and was last granted for onshore wind power in 2008 and for offshore wind power in 2009 (Swedish Energy Authority, 2009).

2.5.2 The Green Certificate System

The Green Certificate System was introduced in 2003, and implies that the government decides that a certain share of the electricity consumption must be generated from renewable sources. The certificates are distributed to the producers of renewable energy, defined as wind power, solar power, geothermal power, wave energy, peat and biofuels. Hydro power plants are to some extent also eligible for certificates. One MWh gives one certificate, which can be sold to actors obliged to buy certificates up to a certain share of their total electricity use. Obliged entities are the energy suppliers, and energy intensive industries that are registered at the Swedish Energy Authority and other energy users that fulfill certain requirements, such as those buying energy directly at Nord Pool. The energy intensive industries are only obliged to possess certificates for the operations that are separated from manufacturing, to maintain international competitiveness. Every year, there is a balancing, and those who fail to meet their quota are penalized. Those entities that have excess certificates can save them for future needs or sell them. If the certificates buyer is an energy supplier, the cost of the certificates is included in the price to the final consumer (Swedish Energy Authority, 2012c).

When the system was introduced in 2003, the quotas were designed to gradually increase until 2010, with the goal of an increase in electricity production from renewable energy by 10 TWh until 2010 (Swedish Government, 2002). In 2009 the system was extended to operate until 2035 with the objective of increasing the amount of renewable electricity with 25 TWh from 2002 to 2035 (Swedish Government, 2009). On January 1st, 2012 the Swedish and the Norwegian certificate markets merged, enabling actors in the merged market to meet their quota obligations in both Sweden and Norway. The agreement applies until 2035 and the goal, in addition to the before mentioned, is to additionally increase the electricity generated from renewables from 2012 to 2035 by 13.2 TWh in each country (Swedish Government, 2010; Swedish Energy Authority, 2010).

2.5.3 Tradable emission permits

With the introduction of the EU´s Emission Trading Scheme (EU ETS) there is a price on carbon emissions in the electricity production in Sweden; previously the electricity production has been fully exempted from the carbon tax due to competitive reasons (Michanek and Söderholm, 2006).

The EU ETS includes all 27 member countries and was introduced in 2005. The trading scheme is regulated by the Emissions Trading Directive (2003/87/EC). The trading system covers about half of the EU's total greenhouse gas emissions, and about a third of the Swedish total emissions. The trading scheme implies a specific cap on the aggregated emissions of the included plants and establishments, and the trading directive regulates how many emission permits to assign to every member country. The companies included are not allowed to have higher emissions than their emission permits, and one emission permit corresponds to the right to emit one ton carbon dioxide (Government office of Sweden, 2012). The ceiling for allowed emissions is reduced over time and so total emissions falls as well. Companies can buy or sell emission permits, or save their allowances for future use (European Commission, 2013).

2.5.4 The carbon and energy tax

Electricity production is exempted from the carbon- and energy tax. This is mainly because electricity is a good that is traded internationally and must out of competitive reasons adapt to the neighboring countries tax ratios. There are however indirect effect of these taxes; for the production of electricity in cogeneration plants fueled with fossil fuels there is a reduced carbon tax on the heating portion of the fuel use. This affects the operating system for various electricity generation options, and hence it affects which power sources that fall on the margin (Sköldberg et al., 2006). The carbon tax effects combined heat and power generating plants, which decrease its competitiveness compared to wind power. This means that the EU´s Emission Trading Scheme, the Green Certificates, (the environmental bonus when it was operating) and the carbon tax interact to affect the production choice of electricity (Johansson, 2004).

2.6 Attitudes towards wind power

Resistance towards wind power is often mentioned as an obstacle in the deployment of wind power in several countries, Sweden among them. Often the resistance occurs on a local level and is associated with visual and noise disturbance and land devaluation. However, studies have shown that the general attitude towards wind power is positive (Ek, 2002).

One explanation to the local resistance is the so called Not-In-My-Backyard (NIMBY) syndrome, which implies that people may be positive towards wind power, but unwilling to have them in the vicinity of their home. Studies shows that this explanation may be too simplistic, for example; a resident study in Scotland found that 27 percent of the residents were against wind power establishment prior to the establishment, and only five percent afterwards (Dudelson, 2000). This might indicate that NIMBY is most prevalent before installations. Ek (2005) found no support for the NIMBY hypothesis in a study conducted among Swedish electricity consumers; the attitudes towards wind power were not different between people with wind power installations visible from their residence and those without this experience.

Wolsink (2007) argues that the general attitude towards wind power is not the same as the attitude towards specific wind turbines. He shows that the general attitude towards wind power is mainly influenced by the environmental benefits and hence the attitude is positive. But when it comes to specific wind turbines, the visual aspect is dominant. He further discuss that the attitudes are not static, as the so called NIMBY theory states. Wolsink concludes that improvements of attitudes can occur after a facility has been constructed, but only when the visual impacts have been satisfactorily dealt with in the eyes of the local population. The idea of fairness he finds to be essential, the residents consider it unfair that the burden of the wind turbine should be placed on them by the decision makers.

2.7 The permit process

In planning and building wind power turbines, several laws and regulations must be considered. The main laws are the Environmental code (EC) and the Planning and Building act (PBA). But other laws may have to be considered as well, e.g. permits may have to be given from the county administrate board if other interests come into conflict, for example with the location of ancient relics. EC is since 1999 the main legislation on environmental matters, with the aim of promoting a sustainable development while meeting different types of environmental concerns, such as protection of natural and cultural environment, but also the management of energy, such as to extract energy from wind and other renewable resources. An application for a permit for big and medium-sized wind turbines must contain an environmental impact assessment (EIA) to identify and describe the direct and indirect effects of the plant. A building permit for wind power requires a permit according to the Environmental code, and the ruling is made by the County Administrative Board's environmental impact assessment committee. It is also required that the municipality has a detailed plan for the building of the wind power plants. Lastly the wind prospectors must receive a building permit from the municipal planning and building committee. In all three steps of the process there is a possibility to appeal the decision by affected parties such as residents and environmental groups. The consequence of this procedure is that it can take several years before the construction of the wind power plant actually can take place. For smaller wind turbines that do not require an environmental assessment a permit according to the Planning and building Act still required (The Swedish national board of housing, building and planning, 2009).

In 2009 the law changed in order to simplify the process and decrease the number of appeals. The requirement of a detailed plan and the building permit was removed. The only permit now needed is a permit according to the environmental code, except in the case where there is great competition between different land use interests. This meant that the municipal authorities lost power in authorizing the building of wind power plants. In order to protect the right of the municipalities, they were given a right of veto, implying that permits according to the environmental code can only be given if the municipality approves (Swedish Government, 2008).

The complexity of the decision process implies that the lead time, i.e. the time between initiation and execution of a project, for wind turbines often exceed five years[1]. This is a long time from an investor's point of view, and there is uncertainty regarding whether the permit will be granted or not (Michanek and Söderholm, 2006). The law change has been criticized since it actually increased the already significant power of the municipalities. A common approach for energy companies and prospectors to create local acceptance of a planned wind power plant is to offer the local residents a compensation for the intrusion that the turbine or plant has on the local environment. The compensation is not enforced by law and the size of the compensation is up to the energy companies to decide, but usually amounts to one percent of the gross value of the electricity produced. Many municipalities have, however one percent compensation inscribed in their wind power policies (Swedish Energy Authority, 2008b).

3. Theoretical Framework

In this section we discuss why, according to economic theory, there is a need for public intervention in supporting wind power, the economic theory behind different types of policy instruments, the effectiveness of the policy instruments, the role of the regulator, as well as the issues related to implementation. This will enable a discussion of the results from an economic point of view, which is presented in section 7.

3.1 Justification of policies supporting renewable energy

When a firm´s or individual´s activity imposes costs or benefits on a third party, without it being reflected in market prices, it is referred to as an externality. An externality is a market

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[1] In fact, several sources conclude that the average process for installing wind power is 5-6 years. See for instance Nordisk Energi, 2/2008 and Bohusvind.se

failure, resulting in that the free market does not maximize welfare. A public intervention is according to economic theory justified if it can increase social welfare. In the case of renewable energy a public intervention can be justified twofold; (i) negative externalities from the use of fossil fuel, primarily greenhouse gases, (ii) the positive externalities associated with technological change (Sterner and Coria, 2012).

It is however important to keep in mind that the existence of an externality in itself is not sufficient to justify government intervention. According to the Coase theorem, in some cases the market participants can themselves negotiate a beneficial solution, which will internalize the externality. However, this requires strong assumptions to hold, such as well-defined property rights and low transaction costs (Coase, 1960).

3.1.2 Externalities affecting wind power

According to Jaffe et al. (2005), negative externalities arise when the cost of pollution is not reflected in the price, which implies that there is no incentive for the firm to minimize the external costs. In a static setting, one needs to compare the marginal cost of abatement and the marginal benefit of cleaner environment to find the efficient policy. Technological innovations, such as new pollution control equipment, results in a decrease in the marginal cost of achieving a unit of abatement. Hence environmental policies also create incentives to invest in technologies that enable them to reduce cost of abatement in the future.

The positive externalities associated with technological change can be divided into two categories; knowledge externalities and adoption externalities. The knowledge externalities originate from the fact that innovators cannot entirely exclude other firms from also benefitting from their knowledge, and thus the innovator is unable to reap all benefits of innovation. More important for the deployment of wind power is probably the adoption externalities, or “dynamic increasing returns”, which imply that the value or cost of a new technology for one user depends on how many others, that uses the same technology. These “dynamic increasing returns” can be created by learning-by-using, as others gain information from observing the new technology adopted by others, learning-by-doing, which implies that production costs are decreasing with production experience, or network externalities, i.e. a technology becomes more valuable to a user when others adopt the same technology (Jaffe et al., 2005).

3.1.3 Interaction of externalities

If the negative externality of pollution is not internalized, the polluting firm does not pay the full cost of their activity. This implies that renewable energy sources have a cost-disadvantage, compared to conventional energy sources and the incentives of firms to invest in renewable energy technologies is low. The development of new technologies is resource intensive, and yield positive externalities. These positive externalities are not captured by the investor, thus he does not have enough incentives to invest in new technology. Hence too little investments in technology for pollution reduction are provided by the market, and government intervention is essential for the development of new technologies. The efficiency of environmental policy is determined by the incentives for technological development. This provides strong motivation for the use of several policies, rather than one policy aimed at emission reductions alone, since it cannot correct for the positive externality associated with technological improvement (Jaffe et al., 2005). The interaction between the externalities are also stressed by Hammar and Söderholm (2005); climate policy instruments in general targets two market failures; greenhouse emissions and positive effects related to the introduction of a new technology. Furthermore the authors state that this implies that it is difficult to distinguish the two and hence it may be difficult to evaluate them separately.

3.2 Review of market based policy instruments

The policy instruments discussed below have all in common that social optimal level is attained by setting the allowed quantity, (as in the case of EU´s Emission Trading Scheme and the Green Certificate System), or price (as the case for taxes and feed in tariffs) based on aggregate abatement and damage curves. The intersection of the two curves is where the socially optimal regulation, or efficiency, is reached. However, in reality, a regulator does not have perfect information about costs and damages, and hence quantity- and price-based instruments may yield different outcomes. Therefore goals are often formulated as desired levels of emissions or production from renewable energy, which might be imperfectly related to the efficient levels. However, cost efficiency is still attainable; which is when a set (or an instrument) achieves the target at the lowest cost (Kolstad, 2000). Hereinafter, when efficiency is mentioned, we refer to the concept of cost efficiency, if nothing else is stated.

Market based policy instruments are favored by economists because of their desired property of static efficiency, i.e. reaching the target at minimized cost at a given point in time. The necessary criterion for static cost efficiency is that the marginal cost of abatement is equalized between firms. In the case of pollution; when pollution is uniformly mixed, there is homogeneity in the damage costs, and marginal abatement costs are heterogeneous, market-based mechanisms are generally more efficient than other instruments, such as command and control (Sterner and Coria, 2012).

3.2.1 Taxes

An environmental charge is referred to as a Pigouvian tax if set equal to the aggregate marginal damages evaluated at the optimal pollution level, where the social marginal cost curve and the marginal damage curve intersect. The tax being equal to marginal damages is a condition for optimality, since the externalities then will be fully internalized. The instrument provides an incentive to abate and it creates an output substitution effect (substitution of dirtier input for cleaner in production). The tax puts a price on every unit of emission and hence allows firms flexibility in finding and implement measures to reduce environmental damage. If the tax is equally high for all actors the cost-efficiency criteria will be met since the firms will reduce their emissions to the point where the marginal cost of abatement equals the tax level. It is however hard to for the regulator to know the exact marginal cost and damage curves and hence set the tax at a sufficiently high (or low) level (Sterner and Coria, 2012).

3.2.3 Tradable emission permits

Tradable emission permits refer to tradable rights to emit carbon dioxide, and implies that polluters are allowed to buy or sell the right to pollute. This increases the price to pollute, which incentivize abatement, since less pollution means that fewer permits need to be bought. When choosing not to pollute, permits can instead be sold to other polluting firms. Costs are minimized since firms that are able to abate at a lower cost; abate more and sell permit credits to firms with higher costs until the marginal cost of one unit of abatement for the different firms are equal, which is the necessary criterion for cost-efficiency. The firms decide themselves the combination of production, abatement and permits, assuming they do not exceed their emission level. When this additional cost is added to carbon emitting energy sources, the attractiveness of renewable energy sources will increase (Sterner and Coria, 2012).

3.2.2 Feed in tariffs scheme

Feed in tariffs imply that public authorities obliges regional or national electric power companies to purchase electricity generated from renewable energy sources at a, by the authorities determined price, during a predetermined time period. These guaranteed tariffs are set either as fixed tariffs above market price, or as in the case of Sweden, as a bonus tariff adding to the present market price. The tariffs cover the cost disadvantage of the renewables compared to conventional sources, and is also generally calculated to grant an investment bonus to the producer of renewable electricity (Ringel, 2006).

If directed at wind power, producers are incentivized to exploit all available sites for wind power until the marginal cost of producing is equal to the feed in tariff, (or feed-in tariff plus energy price). The cost of the subsidy can for example be financed through cross-subsidies among all electricity consumers, or by taxpayers (Menanteau et al., 2003).

3.2.4 Green Certificate System

A quantity-based instrument that enables authorities to make sure that a certain amount of renewable electricity is produced. To reach the target, the government obliges producers, distributors or consumers to produce or buy a certain share of their electricity from renewables. To create a demand for Green Certificates, each distributor or consumer can choose to reach the obliged share by own production of renewable electricity, or by buying the equivalent amount of certificates, which enhances economic efficiency. This implies two separate incomes for the renewable energy producer; the sale of the electricity on the electricity market at standard market price and the sale of the certificate at the certificate market. In the latter, the producer will cover the losses made from the electricity market, where there is competition with conventional energy sources that has a cost-advantage (Ringel, 2005).

The price of the Green Certificates is determined by what is needed to reach the target, or more generally; the marginal cost of the most expensive power source needed to meet the quota minus the energy price. This implies that the uncertainty about future non certificate eligible energy sources generally does not affect the total compensation for renewable energy (Michanek and Söderholm, 2006).

3.3 Dynamic efficiency of policy instruments

We have concluded that static efficiency is a desired property of an instrument, but dynamic efficiency is also crucial in promoting renewable energy. Dynamic efficiency concerns the creation of permanent incentives to technological progress to achieve cost reductions in the long run, so that competitiveness of the new technology will be reached in the future. Regulations provide no incentives to make improvements beyond the standards imposed. Economic incentives on the other hand, create continuous motivation to save on costs of taxes and permits by more improvements in technology, and hence are more efficient (Menanteau et al., 2003).

Hammar and Söderholm (2005) stress the fact that static cost efficiency does not ensure dynamic efficiency. Measures that are expensive in the short run can foster cost-efficiency in the long run, whereas measures that are cheap in the short run might postpone more cost-efficient measures in the long run.

3.3.2 The need of a forward-looking regulator

According to Requate and Unold (2003), if a regulator only takes existing technologies in consideration when implementing a policy, to little or too much investments in abatement technology than what is socially optimal may be the result. Depending on the cost of the investment, some firms will invest. In the case of Tradable emission permits, the initial adoption will decrease demand for permits, hence lower the price and those who do not adopt the new technology can free-ride on the initial firms' adoption. This will not happen if a tax is implemented, since a firm's cost is not affected by other firm's decisions, but this is only true if the tax level is set at the socially optimal level. Otherwise it can also induce over- and underinvestment. Depending on the tax level, firms will either choose to abate or pay the tax, and static efficiency will be reached. In the case of dynamic efficiency, the regulator must also consider the development of new technologies. If the regulator anticipates new technologies, he can commit to an instrument, and commit to wait until the firms have adopted the new technology and then set the level accordingly. If the commitment of the regulator is credible, firms will adopt the technology or not (depending on investment cost as usual), optimal level of adoption will be revealed and the optimal level can be set accordingly.

Hence, according Döllen and Requate (2008), to achieve dynamic efficiency, a regulator should be forward-looking and commit to an instrument, but also commit to adjust the level depending on the development of technology.

3.4 Implementation of policies in practice

Despite effort to determine the right timing and type of instrument to implement, the success of a policy is not assured. When it comes to the actual implementation of the policy, additional issues becomes relevant. For the deployment of wind power, decentralization, uncertainty, and local resistance are crucial aspects to consider, which will be discussed below.

3.4.1 Local planning monopoly

In Sweden the final decision regarding the deployment of wind power is decentralized (see section 2.7). An important determinant is the attitudes among politicians and local government officials and according to Kahn (2003) there is a conflict between the national goals for wind power, and the application of the law at the municipal level. According to economic theory, the reason for decentralization is that the efficient output of a local public good is likely to vary across jurisdictions as a result of differences in preferences and costs, hence local outputs will vary accordingly. However, consumption of non-excludable goods should be the same for everybody in the economy; hence environmental regulation should be coordinated on the widest possible level (Oates, 1999; Casella and Frey, 1992). As discussed in section 2.6, public attitudes towards wind power are divided, which can have implications for the deployment of wind power. According to the median voter theorem, the local representatives are assumed, like voters, to be rational and maximize their utilities by formulating policies insuring their election. The theorem proves that the median voter´s (the voter in the exact middle along some issue dimension) preferred policy is bound to win against any other in a well-behaved voting system (Mueller, 2003).

3.4.2 Distortions of dynamic efficiency

Hammar and Söderholm (2005) stress that when the implementation of a policy is depending on the ductility of the local authorities it can undermine the dynamic efficiency of a policy instrument. For example in the case of the Green Certificate System, there is no guarantee that investments are undertaken where the wind capacity is best suited, which undermines the efficiency in the long run. Another important source of this kind of distortion is uncertainty about future environmental policy, or political uncertainty. Investments might be postponed due to uncertainty regarding if the policy will be operating during the full lifetime of the investment. This type of distortion can also be applied to the Green Certificate System, since it includes both existing and new entities. The conditions for financing for renewable electricity production in Sweden differ mainly due to the uncertainty about the time horizon of the instrument. Initially the Green Certificate System was decided to be in force until 2010, which is a very short period from an investor point of view. This may lead to investors favoring investments in existing capacity, since it requires less financing compared to new investments. The results would be a distortion in favor of existing capacity, which in the long run could lead to a less modern and more expensive renewable energy mix than what is socially optimal.

Wolsink (2007) finds that the negative attitude towards wind power deployment is mainly due to the visual impact. Hence he suggests that to overcome the difference between the nationally set targets and the implementation on a local level, public participation before the place and design of a project is decided is to be induced. He concludes that a top-down decision making will not be as effective as a collaborative approach.

Fridolfsson and Tangerås (2012) argue that to overcome the problem of local resistance the answer is not to centralize the decision. The requirement by municipalities to receive compensation has been criticized, (see section 2.7), but according to the Coase theorem this would lead to an outcome that maximizes total welfare. The municipalities and the investors negotiate a socially optimal fee that would internalize the costs and benefits of the project, decrease the cost for investors and give compensation to the municipalities.

4. Determinants of wind power deployment in Sweden

Following the procedure of Waldo et al. (2012), the dependent variable quantifying the development of wind power is measured by the annual installed capacity in Swedish municipalities (in kW). The data is provided by the Swedish Energy Agency and is collected since 2003, when the Green Certificate System was introduced. The deployment of wind power is affected by several different factors, as suggested by previous literature. The factors are divided into three categories; (i) political and market conditions, (ii) physical municipal specific factors and (iii) social municipal specific factors. Below follows a review of these potential explanatory variables, what previous studies find and our hypotheses. In the end of this chapter, table 2 presents descriptive statistics, including the source of the data. For more detailed information about the variables used in the econometric analysis, please see table 2.

4.1 Political and market conditions

Studies by e.g. Menz and Vachon (2006) and Marques et al (2012) find that public policies are driving factors in the promotion of renewable electricity sources. Carley (2009) and Marques et al. (2010) also finds that market conditions such as the electricity price have an effect on the use of renewable energy.

4.1.1 Policy instruments affecting wind power

Previous studies examining the effect of public policies for renewable energy find different results for the policy instruments. In a panel data study of European countries Marques et al. (2012) finds no significant results of quota obligations or Tradable emission permits being a driver of renewable electricity, whereas they find that subsidies, such as feed-in-tariffs have had a positive and significant effect. Carley (2009), finds that renewable portfolio standards, a form of quota obligation, is a driver of total renewable energy investment and deployment, but do not appear to increase the share of renewable energy in energy portfolios. However, subsides programs were found to be positive and significant in driving both total and the percentage of renewable energy use. Menz and Vachon (2006) also find that renewable portfolio standards have been a significant driving factor in the deployment of wind power in the US.

In this study, variables for the most important policy instruments targeting the deployment of wind power in Sweden during 2003-2012, the environmental bonus and the Green Certificate System, are included. Also policy instruments targeting the reduction of carbon emissions, the carbon tax and Tradable emission permits, which is expected to have an indirect effect on wind power is included. These four policies are hypothesized to have a positive impact on the deployment of wind power.

4.1.2 The electricity price

The price of electricity is one of the single most important factors affecting the profitability of investments in electricity production. The forward prices from Nord Pool are the market's overall assessment of the future system price. The market price must cover the lifetime cost of the investment, excluding the potential revenue from certificate trade and subsidies (Swedish Energy Market Inspectorate, 2007). The electricity price also contains the price of competing energy sources such as oil, coal and natural gas, if these energy sources are used as marginal electricity, which is suggested to have an effect on the use of renewable energy by e.g. Carley (2009) and Marques et al (2010). The market price must cover the lifetime cost of the investment (excluding the potential revenue from certificate trade and subsidies). Hence we expect that the price of electricity will have an effect of the deployment of wind power. However, Carley (2009) finds a negative relationship between the average retail electricity price and share of renewable energy.

4.1.3 The development of technology

The technology of wind power has developed significantly during the period of interest. This becomes particularly evident in the capacity of a wind turbine. During the 1990´s the typical average effect of a wind turbine was 200 kW (IVA, 2002). The average effect of an installed wind turbine in 2011 was 2014 kW (Vindstat, 2013). The economy of scale is evident, as turbines with a greater effect imply that the wind energy can be better utilized and costs of electricity production decrease (IVA, 2002). The trend in Europe is also towards larger turbines, according to the European industry association (EWEA, 2009) and since the middle of the 1980s until 2009 the average cost per produced kWh has decreased with 40 percent. In the econometric analysis, an index of the average installed capacity/turbine in Sweden with base year 2003 is used as a measure of technological development. We expect the variable to have a positive impact on the deployment of wind power.

4.2 Municipal-specific factors

In the study by Waldo et al. (2012), municipal specific factors are expected to drive the deployment of wind power in Swedish municipalities. The authors divide the municipal-specific factors into physical and social factors, and the categorization is used in this study as well.

4.2.1 Physical municipal specific factors

The physical placement of a wind turbine is of vital importance for the profitability, since the production capacity depends on the size of the turbine and the wind conditions, and the production costs decline with the volume produced. Variables measuring the physical conditions and the location of the turbines are included in most previous studies, such as by Waldo et al. (2012), Carley (2009), Vachon and Menz (2006).

Land surface

Large wind power plants are in need of large surfaces; this is considered of great importance for investment decisions for larger power plants (Swedish Energy Market Inspectorate, 2007). Large land surface will most likely also decrease the competition with conflicting purposes of land use (Waldo et al., 2012). Hence we expect that large land surfaces have a positive impact on wind power deployment. However, Waldo et al. (2012) finds no relationship between the land surface of a municipality and its deployment of wind power.

Coastal location

Local winds are created by temperature differences between land and sea. The best wind resources are found at sea and along the coast, and wind power should be installed where wind resources are most favorable (Wizelius, 2007). Hence we expect to find a positive relationship between municipalities with a coastal location and the amount of installed wind power capacity. Waldo et al. (2012) also tests this hypothesis, but find no significant results.

Wind capacity

In 2004, land- and water areas were denoted as national interests for wind power in Sweden by the Swedish Energy Authority, because of their high average wind speed. This implies that there is a government claim to this area, and that the municipalities need to take this into account when planning for wind power deployment. In 2008 additional and larger areas where added as new wind mapping was performed in 2006-2007. The national interest areas together comprise 2.2 percent of Sweden’s surface in 2008, and are important for the valuation of wind power in relation to other interests (Swedish Energy Authority, 2011b, 2012d). We use the national interest from 2008 and will consider the national interest as an implication of good wind conditions and hence expect to find a positive relationship between municipalities with large areas of national interest for wind power and the deployment of wind power. The same expectation was hypothesized by Waldo et al. (2012), but they found no significant results.

4.2.2 Social municipal specific factors

Following the same basic assumption as Waldo et al. (2012) the local social context has an impact on the deployment of wind power. In their study variables for population trends, business climate, environmental interest and tourism are analyzed. To the present analysis, we will add education level, and political governance.

Population growth and population density

Waldo et al. (2012) expect that trends in population may have an effect on the attractiveness of a municipality in regards to both living and industry. Furthermore municipalities with a negative trend are expected to be willing to accept wind power in an attempt to turn the trend. Hence population density and population growth is hypothesized to have a negative impact on the deployment of wind power. The authors find a significant and positive effect of population growth on the deployment of wind power, but find a significant negative relationship with population density. We follow the approach of Waldo et al. (2012), and expect that a negative development in terms of the population is related to a positive development in wind power, and that population density will have a negative effect on the deployment of wind power.

Business climate

According to Kahn (2003) administrative issues and public opposition affects the deployment of wind power and that the attitudes of the local politicians are an important factor for the deployment of wind power at the municipality level. Waldo et al. (2012) expects that business climate is a good measure of the attitudes of local politicians. In their study, they use a ranking of Swedish municipalities in terms of business climate, and expect to find a positive effect on the deployment of wind power. The ranking is a weighting of several factors, such as how local entrepreneurs perceive the service provided by the municipality and the competence of the local politicians and officials (The Confederation of Swedish Enterprise, 2013). We also expect that a good business climate has a positive effect in the deployment of wind power, and use the same ranking to measure this effect. However Waldo et al. (2012) find no support for this hypothesis.

Environmental interest

In a wind power pilot program, Collins et al. (1998) analyzed the characteristics of the individuals who opted for the opportunity to use a certain share of wind power electricity. The authors find that 60 percent of those subscribing to wind power where a member of an environmental organization. The proportion of Green Party votes in the general elections in, 2002, 2006 and 2010 in Swedish municipalities is included to capture a general positive attitude in favor of environmental investments and policies. We expect to find a positive effect of a large share of Green Party voters in the municipality council. The study by Waldo et al. (2012) expects that the interest in the environment in a municipality should point towards more installed wind power, although they found no support for this hypothesis.

Educational level

In the same study mentioned above, Collins et al. (1998) show that a key driver in the choice of using wind power electricity is education levels. This result is also found by Zarnikau (2003), but Ek (2005) finds a small but negative impact off education. We expect an increase in the share of highly educated inhabitants in a municipality to have a positive effect on the deployment of wind power in Swedish municipalities.

Tourism

Conflicting interests with wind power often involve activities in which the experience of the landscape is important, such as recreation, tourism and housing. An example of when tourism has been considered a superior interest to wind power is in Jämtland County, where municipalities agreed that the income from tourism would suffer from the deployment of wind power and hence should be allocated in the municipalities with woodlands instead (MKB Centrum SLU, 2010). Waldo et al. (2012) hypothesize that municipalities with a significant tourism industry will be more negative towards wind power, but finds a significant and positive effect. We use a ranking of municipalities in terms of their attractiveness for tourism, and expect that a high rank is associated with a low amount of installed capacity. Hence tourism is expected to have a negative effect on the deployment of wind power (which implies a positive sign of the coefficient), but with the possibility of conflicting results.

Political governance

A survey performed by Lundmark (1998) found that public opinion regarding constitutional protection of environmental rights differs depending on political party affiliation, where those “on the left” took a “greener stance” than “those on the right”. This difference in attitude is also found when it comes to wind power, as a study by Hedberg (2008) using data collected by the Swedish SOM institute (an opinion polling institute), shows. It is repeatedly found that left-leaning individuals are more positive towards wind power than right-leaning individuals. Assuming that people reveal their true preferences by voting, and vote according to a traditional left/right scale, the political governance in a municipality may have an effect on the deployment of wind power. We therefore expect a left wing political majority to have a positive effect on the deployment of wind power compared to a right wing political majority.

Table 2
Descriptive statistics of the determinants and sources

Variable	Definition	Source	Mean	Std. Dev.	Min	Max
Installed wind power capacity	Annual installed effect per municipality (kW)	Swedish Energy Authority (2013a)	3840	11803	0	181361
Green Certificate price	Average annual certificate price (SEK/MWh)	Swedish National Grid (2013)	235.24	36.89	191.13	294.57
Environmental bonus	Production subsidy (öre/kWh)	Vindstat (2013)	8.71	5.78	0	18.10
Carbon tax (oil)	Tax (SEK/cubic meter) for production of heat in cogeneration plants	Swedish Tax Agency (2013)	724.81	641.70	432.45	2534.00
Trading emission permit price	Average annual future price for EU Trading Emission permits (SEK/ton CO2)	Bloomberg	132.26	57.72	6.02	202.20
Electricity price index	Index of annual retail electricity electricity price (SEK/MWh), base year 1997	Nordpool (2013)	266.67	67.30	178.26	377.36
Technology index	Index of annual installed capacity per turbine in Sweden, base year 2003	Vindstat (2013)	161.67	42.10	100	213.80
Land surface	Land surface (square km)	Statistics Sweden (2013b)	1833.55	2838.90	8.82	20714.66
Coastal location	Dummy equal to 1 if coastal location, 0 otherwise.		0.252	0.434	0	1
Wind capacity	Area denoted as national interest for wind power in km^2	Swedish Energy Authority (2013b)	24.50	58.11	0	649
Population density	Population density (inhabitants/km^2)	Statistics Sweden (2013c)	131.43	466.56	0.20	4617.90

Population growth	Population growth (%)	Statistics Sweden (2013d)	0.001	0.006	-0.030	0.046
Business climate	Ranking of municipalities in business climate (1 being the highest rank)	The Confederation of Swedish Enterprise (2013)	145	83.69	1	290
Green voters	Share of votes for the Green party in municipal elections (%)	Swedish Election Authority (2013)	3.67	2.57	0.10	43.60
Education	Share of highly educated people in the ages 20-74	Statistics Sweden (2013e; 2013f)	0.248	0.086	0.057	0.800
Tourism	Ranking of municipalities in tourism attractiveness, (1 being the highest rank)	HUI Research (2013)	145	84	1	290
Left wing political majority	Dummy equal to 1 if left wing municipal political majority, 0 otherwise	Statistics Sweden (2013g)	0.376	0.4845	0	1
Right wing political majority	Dummy equal to 1 if right wing municipal political majority, 0 otherwise	Statistics Sweden (2013g)	0.409	0.492	0	1
Right /left coalition	Dummy equal to 1 if municipal right/left coalition, 0 otherwise	Statistics Sweden (2013g)	0.215	0.411	0	1
D2003	Dummy equal to 1 if installed wind power capacity before 2003	Swedish Energy Authority (2013a)	0.290	0.454	0	1

No of observation: 2610, except for business climate where the number of observations: 2609

5. Empirical strategy

The primary objective of this analysis is to explore the determinants of wind power deployment in Swedish municipalities during the time period 2003-2011. Therefore we are interested in identifying causal effects of municipal specific, market and political factors, as discussed in previous sections. The data is in panel format, which implies several advantages compared to a cross section format. The data sets are typically larger and the explanatory variables vary over two dimensions, municipalities and time. For the purpose of our study, we are interested in the effect of national policy instruments, which would be impossible to study using a cross section, since these do not vary between municipalities. A panel will thus yield more efficient estimators if changes between time periods are of interest, since the same units are observed repeatedly. Another advantage of panel data is that it reduces identification problem through e.g. its robustness to omitted variables since there is a possibility to include a fixed time-invariant municipal parameter to capture municipal fixed effects (Verbeek, 2008). However, if the unobserved individual heterogeneity is correlated with one of the explanatory variables, the effect of any variable that is constant over time cannot be distinguished from the effect of the municipal fixed effect (Wooldridge, 2002). The amount of installed wind power capacity in municipalities is modeled as follows;

$$IE_{it} = \alpha + \sum_{k=1}^{k} \beta_k X_{kt-l} + \sum_{j=1}^{j} \delta_j Z_{ji} + \sum_{p=1}^{p} \theta_p W_{pit} + \varepsilon_{it}$$

where $\varepsilon_{mt} = \mu_m + \eta_{mt}$, X_{kt} are time-varying public policies that are constant over municipalities, Z_{ji} are time-invariant physical municipal specific factors, W_{pit} time-variant social municipal factors, and *i* represents each of the municipalities, *t* represents the year and l represents the number of lags. We assume that $\eta_{it} \sim i.i.d$ and $N(0, \sigma^2)$ and $\mu_i \sim N(0, \sigma^2)$. A critical assumption for the specification is that all explanatory variables are strictly exogenous, i.e. that $(X, \varepsilon), (Z, \varepsilon)$ and $(W, \varepsilon) \sim i.i.d.$

The dependent variable, IE_{it} measuring accumulated installed wind power capacity in Swedish municipalities over time, is heavily censored. A large fraction of the municipalities have zero installed capacity during the whole period of interest, whereas the positive values are continuous. For this reason we have chosen to use the tobit model, originally developed by Tobin (1958). In a panel data setting, where we assume that the municipal specific effects are random and do not vary over time, the Random Effects (RE) tobit corrects for these properties such that

$$IE_{it}^* = \alpha + \sum_{k=1}^{k} \beta_k X_{kt-l} + \sum_{j=1}^{j} \delta_j Z_{ji} + \sum_{p=1}^{p} \theta_p W_{pit} + \varepsilon_{it}$$

$$IE_{it} = IE_{it}^* \text{ if } IE_{it}^* > 0$$

$$= 0 \ otherwise$$

$$\Rightarrow \quad IE_{it} = \max(0,\ \alpha + \sum_{k=1}^{k} \beta_k X_{kt-l} + \sum_{j=1}^{j} \delta_j Z_{ji} + \sum_{p=1}^{p} \theta_p W_{pit} + \varepsilon_{it})$$

One can think of the above as a maximization problem, where for some economic agents the corner solution $IE = 0$, will be the optimal solution. Using OLS on the whole sample in this setting would not be optimal, firstly, when$y \geq 0$, $E\ (y|x)$ is non-linear in x, (unless the range of x is fairly limited). Secondly, the model can predict negative probabilities or probabilities greater than one. The tobit model allows estimation for the distributions; $P(y = 0|x)$ and $E(y|x, y > 0)$. Since our sample contain all the Swedish municipalities there is no need to consider the possibility of sample selection bias. The use of an RE tobit model assumes that the same variables effecting the probability of nonzero observation determine the magnitude of installed capacity, i.e. that the same variables explains the decision to install wind capacity and the magnitude of installed capacity, which we assume holds. The tobit model enables the estimation of the partial effect of the explanatory variables for different outcomes such that:

- $E(y|x)$ measures the expected value of installed capacity (for both zero and positive capacity).
- $Prob(y^* > 0|x)$ measures the probability of having wind power.
- $E(y|x, y > 0)$ measures the expected installed capacity given $y > 0$.

(Wooldrige, 2002). For the purpose of our analysis, marginal effects for all these three alternative outcomes will be calculated; this enables the analysis of the impact of the different determinants for two different decisions; the decision to install wind power, and the decision of how much wind power to install given that the municipality has installed capacity larger than zero. We will also consider the size of the marginal effects of the determinants, as the impact of the variables may differ in magnitude.

Data issues

In section 2.7 the permit process is discussed, and it is stated that it is often prolonged. This implies that it can take several years before the construction of the actual turbine or plant can take place, on average five years. It would have been optimal to instead analyze the planned effect each year on a municipal level, since then the effect of the policy instruments would more likely be seen the same year on the decision to install. However this data is not available at the municipal level. The dependent variable is annual installed capacity in Swedish municipalities which might imply that the policy instruments have a lagged effect of approximately five years. This delayed effect might also be true for the electricity price. Therefore it may be suitable to introduce lagged effects of the policy instruments, we will determine if lags are appropriate and the number of lags by comparing the log likelihood values for the different estimations.

It is possible that the variables included will suffer from multicollinearity. If this is the case some variables will have to be omitted from the regression. When omitting variables, it is important to keep in mind that it can result in an overestimation of the true effect of the included variables correlated with the omitted variables.

There is no way of testing for exogeneity, when using a tobit model. We argue however that the regressors used have the required property of exogeneity. The municipal specific factors coastal location and wind capacity are exogenous by definition (given by geographical conditions). The population density in different municipalities can be argued to follow the same trend for many decades, i.e. low populated areas decrease in density and highly populated areas are increasing in density, this is due to structural changes in our economy and can hence be considered exogenous in this setting. A municipality's level of education is arguably given by employment opportunities and universities in the municipalities, wind power will not induce an increase in education per se. Business climate is determined by local politicians and officials attitude towards entrepreneurs, and we assume that the causality goes from a good business climate to installed wind power. Environmental interest is an innate property among the residents and is assumed to cause a positive attitude towards wind power. The same reasoning is applicable to political majority, if the residents vote according to the traditional right-left scale, political majority is due to an innate attitude towards how societal issues should be handled. The policy instruments is often a result of directives from the EU, i.e. decisions taken on an international level and hence cannot be considered a result of installed wind power on the municipal level.

Economic theory suggests that development of technology and the use of the new technology are decided simultaneously through the "dynamic increasing returns" (see section 3.1.2). Hence the technology index could be endogenous. We therefore perform the regression without the technology index and include time dummy variables instead, to validate our results. If there are no major changes, this will indicate that the technology index is exogenous.

We will perform the regression with different sample periods to account for the possibility of endogeneity due to that the dependent variable contains installed capacity before 2003. This may cause endogeneity, since the included explanatory variables are insufficient in explaining the diffusion of wind power in the time period before 2003 and some unobserved factors might be correlated with the included independent variables. Therefore we estimate an RE tobit model explaining the accumulated installed wind power capacity from 2004 to 2011, (excluding the installed capacity previous to, and from 2003). The RE Tobit model for the restricted sample (2004-2011) will be performed twice. This is due to that when subtracting accumulated capacity before 2003, it will imply zero installed capacity for those municipalities who installed capacity before and during 2003, but did not increase the capacity afterwards. To account for this; a dummy for installed capacity in 2003 will be included (d2003). However, this dummy variable might cause endogeneity (it is basically a lagged dependent variable) and hence we perform a tobit, excluding the dummy as well.

We will also attempt to validate our results by comparisons with other suitable models such as the RE probit model, which should give similar results in terms of signs and significance if the assumptions that the same factors drive the decision of installing wind power and the magnitude of wind power, holds. The fixed effects OLS has due to the linear transformation no issue of endogeneity, and hence will support our results if similar results are obtained. Finally, we will perform tobit regression for year 2011 only (a cross section), to compare the results with the use of panel data.

6. Results

Table 3 below presents the results from the RE tobit model for the log of installed capacity of wind power, until and during the time period 2003-2011. To enable the transformation into log format with a large fraction of observations being zero, the dependent variable is treated as; $log(installed\ capacity + 1)$. The same procedure is performed with explanatory variables that are transformed into log format and contains observations being zero.

Table 3
RE tobit on municipal-level with dependent variable: accumulated installed wind power capacity until 2003-2011 in log form

Variables	**Coefficients**	**ME P(y>0|x)**	**ME(Y|x, y>0)**
Political and market factors			
Green Certificate price $_{t-5}$	0.0038*** (0.0010)	0.0001*** (0.0000)	0.0014*** (0.0003)
Trading emission permits price $_{t-5}$	0.0048***(0.0012)	0.0001*** (0.0001)	0.0018***(0.0004)
Electricity price index $_{t-5}$	0.0065*** (0.0018)	0.0002*** (0.0001)	0.0024*** (0.0007)
Technology index $_{t-5}$	0.0163*** (0.0035)	0.0006*** (0.0001)	0.0061*** (0.0013)
Municipal specific factors			
Log wind capacity	0.3858 (0.2932)	0.0145 (0.0111)	0.1437 (0.1100)
Log population density	-0.0858 (0.3027)	-0.0032 (0.0114)	-0.0320 (0.1128)
Business climate	-0.0001 (0.0020)	-0.0000 (0.0001)	-0.0004 (0.0007)
Log green voters	-0.3058 (0.2308)	-0.0115 (0.0087)	-0.1139 (0.0861)
Tourism	-0.0282*** (0.0058)	-0.0011*** (0.0002)	-0.0105*** (0.0023)
Left wing political majority	0.8421*** (0.2527)	0.0317*** (0.0096)	0.3170*** (0.0971)
Right/left coalition	-0.0093 (0.2438)	-0.0003 (0.0092)	-0.0034 (0.0910)
Constant	-3.6070* (1.749)		
Rho	0.9426		
Wald	624.61***		
Log likelihood	-3287.5736		
No. of observations	2609		
No. of municipalities	290		

Notes: ME is short for marginal effect. Environmental bonus, carbon tax, land surface, coastal location and population growth are omitted due to multicollinierity. Standard errors are reported in parentheses. ***,** and * denote parameter significance at 1,5 and 10 percent levels, respectively.

In the above regression the included policy instruments and the index of yearly average electricity prices are lagged five years. By comparing the log likelihood values resulting from the different model specifications, the regression with five lags, which is presented in table 3 above, is chosen since it has the highest log likelihood value.

Due to high correlations between the explanatory variables, some have been omitted in the regression. As can be seen in the correlation matrix in table A2 in appendix, Green Certificate price is highly correlated with the environmental bonus (-0.99), most likely due to that upon its introduction, the environmental bonus began to be phased out. The same problem occurs when the EU ETS scheme is introduced in 2005, and the carbon tax is lowered to avoid double taxation, and hence the carbon tax is omitted. Land surface is omitted due to its high correlation with both wind capacity (0.53) and population density in particular (-0.70). The share of educated people in the municipality and population growth is omitted due to high correlation with population density. Densely populated municipalities are primarily major and bigger cities, and their suburbs; regions that attract educated people and have more employment opportunities. The variable for coastal location was omitted due to a noticeably large coefficient, which probably is due to correlation with unobserved municipal specific factors. However, omitting it implies that it will still be controlled for since it will be included in the municipal specific effects, which is also the case for land surface. This implies that the marginal effects need to be interpreted with caution.

The results from the main regression model are presented below.

Political and market factors:

- A positive and significant relationship between Green Certificate price and installed wind power capacity is found, as expected. An increase of 1 SEK per MWh produced electricity results in 0.38 percent increase in installed wind power capacity on average. The total marginal effect is most likely inflated by the negative correlation with the environmental bonus, as discussed above.
- A positive effect is also found for the EU ETS price on wind power deployment; an increase in the price of Trading emission permits by 1 SEK/ton CO^2 will results in a 0.48 percent increase in wind power capacity on average. The effect is statistically significant and has the expected sign. The total marginal effect is most likely inflated by the negative correlation with the EU ETS price, as discussed above.
- The electricity price and technology development is found to have a significant and positive effect on wind power deployment, as expected.

Municipal specific factors:

- No statistically significant effect is found for wind capacity, population density, business climate, or the coefficient for green voters on installed wind power capacity.

- A significant relationship between tourism and wind power deployment is found, and the sign is negative, which is not expected. The more attractive a municipality is for tourism, the more wind power capacity is installed. A one level degradation in the ranking of attractiveness for tourism decreases wind power capacity by 2.82 percent.
- A left wing political majority is found to have a positive and significant effect on the deployment of wind power at the municipal level, compared to a right wing political majority. However, the magnitude of the coefficient is unreasonably large (132 percent compared to a right wing political majority). This is most likely due to that the variable captures some of the fixed municipal effects and hence the coefficient must be interpreted with caution. When decomposing the marginal effects we get more plausible results; for the expected value of installed capacity given that installed capacity is positive, the marginal effect is 3 percent for the probability of having wind power at all, and the marginal effect for the expected installed capacity, given that installed capacity is positive, 37 percent.
- Having a left wing majority has the largest marginal effect on the probability of installing wind power, followed by the tourism variable; the same variables have the largest marginal effect on the level of installed capacity as well.

Comparison of magnitudes of the marginal effects

For the two policy instruments, we can compare the magnitudes of the marginal effects directly[2]. The Green Certificate price and the EU ETS price have almost identical magnitudes for all marginal effects, which imply that they have an almost equivalent effect on the deployment of wind power. For the other significant variables the comparison is not as straight forward, but to get an idea of how the variables effect the deployment of wind power, the marginal effects for the variables is multiplied with their standard deviations, which can be seen in table 4 below. Both the electricity price and the development of technology have larger effects for a change by one standard deviation, than the policy instruments, for all marginal effects, which indicate that the market conditions have a greater impact than the policy instruments on both the decision to install wind power and the magnitude of installed wind power capacity. Interestingly, the social municipal specific factors appear to have the

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[2] The production of 1 MWh electricity in coal condensing power production emits 1 tone carbon dioxide (Swedish Energy Authority, 2008a), and the EU ETS price is in SEK/tone carbon dioxide. The Green certificate price is measured in SEK/MWh. Hence the magnitudes of the marginal effects are comparable.

largest impact out of the significant determinants. This is especially the case for the level of installed capacity.

Table 4
Comparison of magnitudes of significant determinants
(Standard deviation*Marginal Effect)

Variables	Std.Dev	Std. Dev * Coefficient	Std. Dev * ME P(y>0|x)	Std. Dev * ME(Y|x, y>0)
Green certificate price $_{t-5}$	36.89	0,14018	0,00369	0,05165
Emission permit price $_{t-5}$	57.72	0,27706	0,00577	0,10390
Electricity price index $_{t-5}$	67,3	0,43745	0,01346	0,16152
Technology index $_{t-5}$	42,1	0,68623	0,02526	0,25681
Tourism	84	2,36880	0,09240	0,88200
Left wing political majority	0,4845	0,40800	0,01536	0,15359

Sensitivity analysis

Overall we get similar results in the models used to validate our main model. The results from the regressions can be seen in table A1 and A2 in Appendix. The policy instruments have the same signs and significance across the different models, but for the municipal specific factors the results differ somewhat. Population density becomes significant in the linear fixed effect and probit models, but the coefficient is large, suggesting it is inflated somehow in these models. The variable for having a left wing political majority loses significance in all control regressions, indicating that the result should be interpreted with caution. When we estimate the model without the technology index and include year dummy variables, we get very similar results, which is reassuring.

Compared to a cross section for the installed capacity in 2011, where the municipal factors are analyzed, similar results to the main model is found, but the variable for wind conditions is positive and significant and population density has a significant and negative effect.

7. Discussion and conclusion

This thesis focus on a panel containing Swedish municipalities during the time period 2003-2011, with the purpose of analyzing what determines the deployment of wind power at the municipal level. An empirical analysis of four different policy measures aimed at reducing carbon emissions or increasing renewable energy use, as well as municipal specific factors, both physical and social is conducted. We show that both policy instruments and municipal factors play a role in the deployment of wind power, and our results indicate that the latter has a larger impact.

The Green Certificate System and EU´s Emission Trading Scheme are found to have a positive effect, in accordance to what Menz and Vachon (2006) and Carley (2009) find, but the contrary to what Marques et al. (2012) find. This supports the implementation of the Green Certificate System and implies that the instrument is a driver of wind power deployment in Sweden. The results also show that the EU ETS has a positive effect on the deployment of wind power. Our results indicate that despite concerns of distortions when implementing these policies, such as political uncertainty and free-riding, the instruments have a positive effect on the deployment of wind power. Unfortunately we are unable to analyze the impact of the environmental bonus and the carbon tax, because if multicollinierity. This is not surprising since the policies interact and thus it is difficult to distinguish their individual effects. As expected, market conditions such as electricity prices and technology development are significant drivers of wind power deployment. These factors, together with the public policies make wind power more attractive in the eyes of the investor.
We find that municipal specific factors are significant drivers of wind power deployment, which is in line with the findings of Waldo et al. (2010). However physical factors, such as wind capacity do not appear to have a significant effect, which corresponds to the results found by Waldo et al. (2012). The insignificance can be due to many reasons, e.g. conflicts with areas of national interest for other purposes, such as wildlife preservation. The fact that wind capacity does not seem to have a significant impact on the deployment indicates that wind power is not installed where the physical conditions are optimal and where it is efficient in the long run. Instead deployment may be occurring where social conditions are suitable, which is often suggested by literature.

We found a significant positive impact of having a left wing majority compared to having a right wing majority, which was expected. If left oriented individuals take a “greener stance” as suggested by Lundmark (1998). This indicates that if individuals reveal their preferences according to a left right scale by voting, left wing sympathizer’s attitudes towards environmental issues will affect the deployment of wind power. However, this result needs to be interpreted with caution since the sensitivity analysis does not validate the result.

Tourism is also found to have a positive effect on the deployment of wind power, which corresponds to the findings by Waldo et al. (2012). This was not expected, as it is many times hypothesized that tourism and wind power are conflicting interests. This is an interesting result since it suggests that the two interests need not be conflicting as often feared.

We do not find any significant effect of the remaining municipal factors; business climate, environmental interest and population density. This concurs with the findings of Waldo et al. (2012), except for population density, which they find have a significant and negative effect on wind power deployment. The reason why we do not find any effect in a panel setting may be that population density does not vary much over time within a municipality. A cross section may instead overestimate the effect, since it only studies the effect between municipalities at a given point in time. When we perform a regression and restrict the sample to the installed capacity in 2011, the coefficient for population density is found to be significant and negative, but with a relatively large magnitude, which might indicate that a cross section overestimate the effect of population density.

In conclusion, the difference in wind power deployment between Swedish municipalities is not only a matter of physical conditions, as optimal allocation requires. For the policy maker, it is important to be forward-looking as well as attend to local conditions when setting targets and implementing policies. Involving the local residents in an early stage and implement suitable tools for compensation will enhance the effect of the policy instruments and help in reaching the set target. Economic theories are, if nothing else, agreeing that the proper incentives give the optimal outcome. The effect that a power turbine or plant have on its surroundings appears to constitute a negative externality to those that are affected. For there to be a willingness to wind, letting the parties bargain in a Coasian tradition may be one way forward.

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Appendix

Table A1

Regression estimates for sensitivity analysis with dependent variable: accumulated installed wind power capacity in log form

	RE Tobit 1 (excl. d2003)	**RE Tobit 2 (incl. d2003)**	**FE Linear**	**RE Probit**
	2004-2011	2004-2011	2003-2011	2003-2011
Variable	**Tot. average ME**	**Tot. average ME**	**Coeff.**	**ME**
Political and market factors				
Green certificate price$_{t-5}$	0.008*** (0.002)	0.008*** (0.002)	0.002** (0.001)	0.009*** (0.009)
Emission permits price$_{t-5}$	0.007*** (0.002)	0.007*** (0.002)	0.003*** (0.001)	0.007*** (0.002)
Electricity price$_{t-5}$	0.012*** (0.003)	0.012*** (0.003)	0.003*** (0.001)	0.008*** (0.003)
Technology index	0.033*** (0.006)	0.033*** (0.006)	0.007*** (0.002)	0.0367*** (0.007)
Municipal specific factors				
Coastal location	-	-	omitted	-
Log wind capacity	0.536 (0.378)	0.554 (0.344)	omitted	0.130 (0.166)
Log population Density	-0.020 (0.414)	-0.488 (0.389)	-9.073*** (1.300)	1.218*** (0.279)
Business climate	0.004 (0.003)	0.003 (0.003)	-0.001 (0.001)	-0.000 (0.003)
Log Green voters	-0.432 (0.392)	-0.463 (0.387)	-0.2126 (0.100)	-0.392 (0.321)
Tourism	-0.023*** (0.008)	-0.009 (0.007)	omitted	-0.057*** (0.005)
Left political majority	0.645 (0.411)	0.651 (0.408)	0.210 (0.136)	0.097 (0.474)
Right/left coalition	-0.182 (0.406)	-0.232 (0.402)	-0.067 (0.129)	-0.690 (0.539)
D2003	-	10.426*** (1.309)	-	-
Constant	-21.091*** (2.429)	-16.190*** (2.279)	31.916*** (4.33)	-9.113*** (1.400)
Rho	0.914	0.889	0.989	0.996
Wald	691.35***	735.89***		262.28***
Log likelihood	-2472.640	-2445.851		-470.522
R-sq within			0.213	
R-sq between			0.001	
R-sq overall			0.000	
F-test N(0,1)			69.24***	
No. of observations	2320	2320	2609	2609
No. Of municipalities	290	290	290	290

Notes: ME is short for marginal effect. Environmental bonus, carbon tax, land surface, coastal location and population growth are omitted due to multicollinierity. Standard errors are reported in parentheses.***,** and * denote parameter significance at 1,5 and 10 percent levels respectively. In the FE Linear model, robust standard errors are used to correct for heteroskedasticity.

Table A2

Regression estimates for sensitivity analysis with dependent variable: accumulated installed wind power capacity in log form

	Re Tobit	**Tobit**	**Tobit**	**Tobit**
	2003-2011	2011	2011	2011
	Total average	**Total average**	**Marginal effect**	**Marginal effect**
Variable	**Marginal effect**	**Marginal effect**	**P(y>0|x)**	**E(Y|x, y>0)**
Political and market factors				
Green certificate price	0.004* (0.002)			
Emission permit price	0.004*** (0.001)			
Carbon tax	0.000 (0.000)			
Electricity price index	0.002 (0.002)			
Technology index	0.032*** (0.003)			
Municipal specific factors				
Log wind capacity	0.390 (0.293)	0.594** (0.2770)	0.031** (0.015)	0.371** (0.173)
Log population density	-0.158 (0.303)	-0.120 (0.3927)	-0.006 (0.021)	-0.069 (0.245)
Business climate	-0.001 (0.002)	0.002 (0.0069)	0.000 (0.000)	0.001 (0.004)
Log Green voters	0.164 (0.215)	0.054 (0.8314)	0.003(0.044)	0.034 (0.519)
Tourism	-0.027*** (0.006)	-0.018*** (0.0058)	-0.001*** (0.000)	-0.011*** (0.004)
Left wing political majority	1.045*** (0.255)	-2.655*** (1.1554)	-0.141** (0.061)	-1.608** (0.677)
Right/left coalition	0.032 (0.247)	-0.121 (1.3241)	-0.006 (0.070)	-0.075 (0.821)
Constant	-6.926*** (1.783)	4.950*** (2.2013)		
Rho	0.941			
Wald	596.12***			
Log likelihood	-3296.222	-639.780		
LR chi2		24.75***		
Pseudo R2		0.019		
No. of observations	2609	290	290	290
No. Of municipalities	290	290	290	290

Notes: Environmental bonus, carbon tax, land surface, coastal location and population growth are omitted due to multicollinierity. Standard errors are reported in parentheses.***,** and * denote parameter significance at 1,5 and 10 percent levels respectively.

Table A3
Correlation matrix, years until 2003-2011

	Log Installed capacity	**Green certificate Price$_{t-5}$**	**Emission permit price$_{t-5}$**	**Environmental Bonus$_{t-5}$**
Log Installed capacity	1.0000			
Green Certificate price$_{t-5}$	0.1615	1.0000		
Emission permit price$_{t-5}$	0.1422	0.5660	1.0000	
Environmental bonus $_{t-5}$	-0.1569	-0.9881	-0.5883	1.0000
Tax oil$_{t-5}$	-0.0967	-0.4709	-0.6457	0.4774
Electricity price index$_{t-5}$	0.1710	0.7365	0.5836	-0.7317
Technology index	0.1742	0.7694	0.5893	-0.7149
Log land surface	0.1964	-0.0003	-0.0002	0.0003
Coastal location	0.2879	-0.0002	-0.0001	0.0002
Log wind capacity	0.0592	-0.0003	-0.0002	0.0002
Log population densinsity	0.0170	0.0018	0.0017	-0.0018
Log population growth	0.0518	-0.0011	-0.0152	0.0094
Business climate	0.0355	-0.0001	-0.0003	0.0002
Log green voters	0.1278	0.1428	0.2405	-0.1486
Log education	0.1184	0.1438	0.1198	-0.1371
Tourism	-0.2224	0.0005	0.0003	-0.0004
Left wing political majority	-0.1210	-0.0530	-0.0044	0.0408
Right wing political majority	0.0702	0.0901	0.0498	-0.0765
Right/left coalition	0.0588	-0.0454	-0.0545	0.0435

	Tax oil$_{t-5}$	**Electricity price index$_{t-5}$**	**Technology index**	**Log Land Surface**
Tax oil$_{t-5}$	1.0000			
Electricity price index$_{t-5}$	-0.1996	1.0000		
Technology index	-0.3029	0.8698	1.0000	
Log land surface	0.0000	-0.0004	-0.0005	1.0000
Coastal location	0.0000	-0.0003	-0.0003	0.1988
Log wind capacity	0.0000	-0.0004	-0.0005	0.5237
Log population densinsity	-0.0012	0.0022	0.0021	-0.7490
Log population growth	0.0279	0.0132	0.0224	-0.4175
Business climate	0.0012	0.0007	0.0006	0.4334
Log green voters	-0.1549	0.1632	0.1553	-0.1087
Log education	-0.0756	0.1531	0.1627	-0.2749
Tourism	-0.0000	0.0006	0.0008	-0.4959
Left wing political majority	-0.0221	-0.0705	-0.0792	0.1330
Right wing political majority	-0.0022	0.1149	0.1238	-0.2186
Right/left coalition	0.0287	-0.0545	-0.0547	0.1048

	Coastal location location	Log wind capacity capacity	Log population density	Log population Growth
Coastal location	1.0000			
Log Wind capacity	0.1331	1.0000		
Log population densinsity	0.1979	-0.3848	1.0000	
Log population growth	0.1599	-0.2280	0.6697	1.0000
Business climate	0.0203	0.2288	-0.4982	-0.4691
Log green voters	0.1725	-0.1072	0.4139	0.3603
Log Education	0.1778	-0.1799	0.6338	0.5859
Tourism	-0.3410	-0.2236	0.1593	0.0195
Left wing political majority	0.0396	0.0950	-0.1021	-0.1909
Right wing political majority	0.0059	-0.1315	0.1986	0.2244
Right/left coalition	-0.0538	0.0454	-0.1173	-0.0435

	Business climate	Log green voters	Log education	Tourism
Business climate	1.0000			
Log green voters	-0.1414	1.0000		
Log Education	-0.4113	0.5019	1.0000	
Tourism	-0.1145	-0.1075	-0.1749	1.0000
Left wing political majority	0.2964	-0.0778	-0.1355	0.0160
Right wing political majority	-0.4025	0.0330	0.2226	0.0264
Right/left coalition	0.1322	0.0523	-0.1066	-0.0505

	Tourism	Left wing political majority	Right wing political majority	Right/left Coalition
Tourism	1.0000			
Left wing political majority	0.0160	1.0000		
Right wing political majority	0.0264	-0.6463	1.0000	
Right/left coalition	-0.0505	-0.4061	-0.4349	1.0000