Regional pathways of smart specialization: the case of wind energy in Spain

Cristian Matti[1]

Davide Consoli[2]

INGENIO (CSIC-UPV)[3]

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1. Introduction

The concept of Smart Specialisation has gained ground in the policy debate concerning the promotion of efficient use of public investments within well-identified geographical and institutional contexts (Foray et al, 2012; OECD, 2012). The roots of this concept lie in the scholarly tradition that sees regional innovation as the thrust of economic growth and prosperity in the modern globalized economy (Cooke, 2001; Asheim and Isaksen, 2002). The implementation of smart specialisation requires prior sound knowledge of regional physical and intangible assets and tight coordination between businesses, public entities and knowledge institutions. Though external knowledge sourcing and cooperation are an integral part of innovation strategy via smart specialization, the criteria for inclusion of potential partners are adjusted to the priority of avoiding unnecessary duplication and unviable collaborations.

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[1] Email: crimat@ingenio.upv.es

[2] Email: davide.consoli@ingenio.upv.es

[3] Institute of Innovation and Knowledge Management INGENIO (CSIC-UPV) - Polytechnic University of Valencia. Address: Ciudad Politécnica de la Innovación | Edif 8E 4º | Camino de Vera s/n | 46022 Valencia | tel. +34 963 877 048 | fax +34 963 877 991

In spite of much progress on the conceptual understanding of smart specialization, evidence on actual implementation and on the practical implications is still scant. This is partly due to the complex nature of the governance involved in smart specialization, especially when policy design refers to multi-level decision-making in multi-actor contexts (Laranja et al, 2008). But the pressing question remains: what is the route to smart implementation? And, perhaps more cogently, is there only one possible route?

The present paper seeks to address these questions by analysing and comparing pathways of Wind Energy development across Spanish regions. It begins by presenting the key concepts to be used to explore pathways of smart specialization second, it moves to describe the key capacities developed behind the emergence of the wind energy sector in Spain. These spectrum of "innovative capacities" that relate to complementary spheres of intervention namely industrial capacity, organizational capacity and research capacity will guide the benchmarking of Spanish regions in order to identify possible patterns of specialization. Finally, a deeper analysis of three regions will be presented in order to highlight linkages and complementarities in the innovative capacities that may explain the creation of different but smart pathways of specializations.

The empirical study will be based on the triangulation of information from case study research. Analysis of these data will be complemented by content analysis of documents and interviews as well as statistical procedures.

2. Pathways of smart specialization

Spain has been at the forefront of renewable energy promotion since early days. The initial emergence of renewable markets of the 1990s progressively gave way to ever more sophisticated mechanisms for the impulse of energy trade in the decade 2000-2010. Through a wise mix of investments in infrastructures and of programs for the reconversion of existing knowledge capacity from traditional sectors (such as aircraft, metal mechanic, electronics, construction and naval industry) Spain has outgrown expectations and competitors (Meyer, 2007; Del Rio Unruh, 2007) until becoming, in 2010, Europe's leading producer of wind energy. Using qualitative data we illustrate the contingent nature of policy, and the diversity of routes that have been used to promote smart specialization around what many consider an ultimately mature technology (EWEA, 2009).

The tale of Spanish regions would not look so triumphal had it not been for the pivotal role of specific regional actors. The various forms of innovative capacity that enable the latent potential at heart of Wind Energy development stem from a series of multi-level interactions between public and private sectors as well as with actors operating outside of the local sphere. European legislation and targeted support to R&D were the formal triggers for the variety of responses observed across regions. Renewable energy policy acquired a strongly localized flavour in Spain when local characteristics such as natural resource endowment, latent potential from existing infrastructures and propensity towards specific paths of technological specialization materialized.

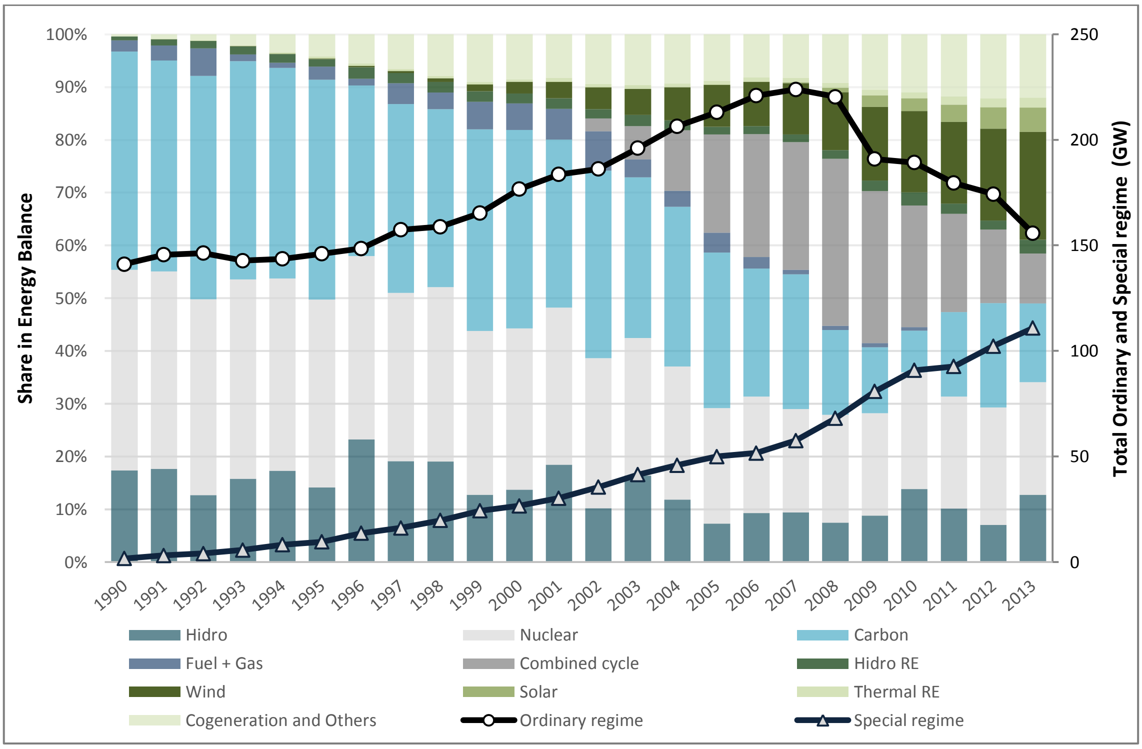
The pathways of smart specialization will be analysed by focusing on the generation of production capacity (energy production) and the implementation of innovation capacity (technology development) against the specificity of regional backgrounds such as industrial history and research capacity. These pathways have been facilitated by the juxtaposition of governance and decision-making mechanisms together with a wide mix of policy instruments. Taking these dimensions as key constructs we identify three paradigmatic pathways of regional development, namely Galicia, Castilla y Leon and the Basque Country. These cases provide a wide perspective on the diversity of routes for the implementation of smart specialization. We frame the analysis in the broader context as defined by the timing of critical actions, their evolution and the relative positioning of each region within a changing system of interactions.

3. Development of Spanish wind energy sector

The emergence of the wind energy sector in Spain has had as a background not only a set of institutional changes in term of national and international energy and climate change policy but also the period of mayor economic growth in last decades. The energy sector, even when it is not significant as share of GDP (3% in 2008), has experienced a critical evolution of structure and level of activity during the last decades. The energy balance in Spain has changed significantly since the special regime to foster renewable energy production was launched in 1997. Capacity under the ordinary regime[4] increased 42%, while capacity under the special regime reached 522% leading by wind, cogeneration and solar energy (see Fig 9). More specifically, total wind power capacity rose by 3,820% in the period 1997-2008 based in the increase in the number of infrastructures (i.e. wind farms) or the upgrade of installed capacity (i.e. introduction and replacement of wind turbines).

Figure 1 Evolution of Spanish energy Balance 1990-2013

[4] Ordinary regime include the set of traditional technologies for production of electricity such as thermal plant based in gas and coal as well as nuclear power an hydroelectric plants. Special regime include all renewables technologies and co-generations plants.



Source: own elaboration based in REE (2013)

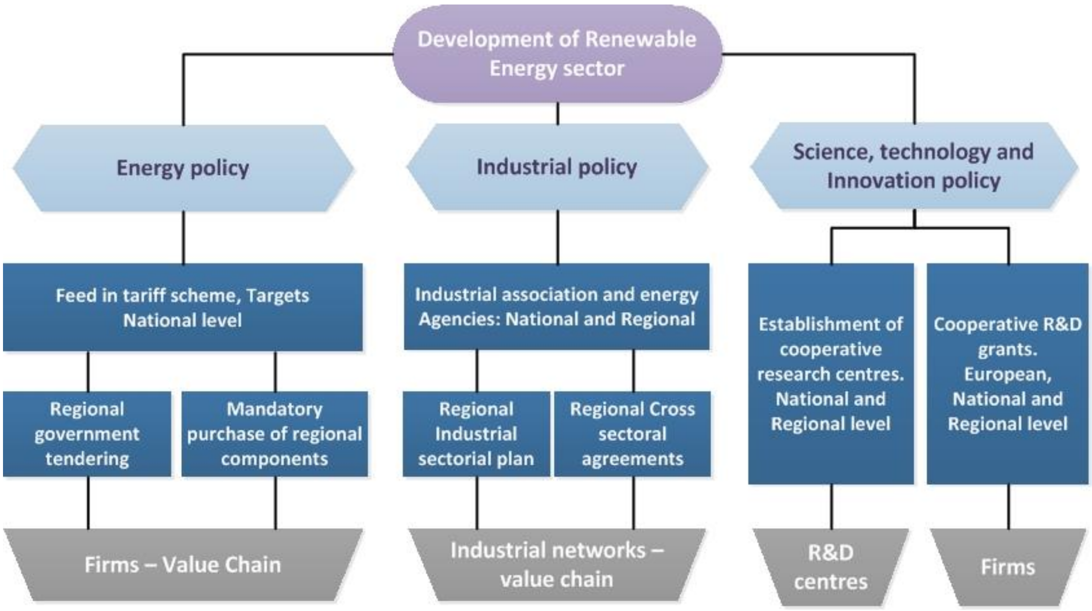
The remarkable expansion of wind energy sector is due to the intersection of various processes. On the one hand, European Union (EU) regulation has provided a solid platform for harmonizing incentives and opening up opportunities though a multi-level implementation process of a mix of polices on energy, industrial and innovation domains. The wind plans implemented at regional level were critical in the creation or wind power capacity.

On the other hand, demand for alternative energy has grown significantly and, together with the opening of new peripheral markets, has engendered significant transformations in the structure of supply. In other words, the emergence of the wind energy sector has been based in two pillars: the energy production and the manufacturing of renewable energy technology. These two pillars have been supported by a wide platform of supranational and national directives, where Spanish regional governments have designed and implemented development strategies based on the mobilization of locally available assets. This resulted in different pathways of specialization regarding industrial, research and policy capacities across regions, and a rather rich spectrum of development trajectories that leverage on and feed back into regional-specific tangible and intangible assets. The pathway followed by different Spanish regions are then briefly explained as follows.

3.1. Overview of general economic context and policy background

The policy portfolio fostering renewables energy includes a range of mechanisms linking energy and industry policy to foster innovation in emergent sectors. This set of instruments for application at different levels, may belong to specific energy policy categories or be part of supply and demand side measures to support industry more generally. This policy mix has stimulated the sector evolution toward a more integrated and diversify value chain. Main changes have been based in liberalization and creation of a market as well as the pursuit of different environmental objectives and commitments. In Spain, while financial stimuli such as Feed in Tariff (FIT), RREE targets and R&D programmes are designed at national level, their implementation and accompanying environmental, energy and industry policies rely on local assets including natural resources, and organizational and regulatory competences. At local level, policy has created employment and market opportunities on the back of existing R&D and industrial capacity.

Figure 2 Policy domains and main instruments fostering the development of wind energy sector



Source: own elaboration based in Magro & Wilson (2013)

The policy portfolio encompasses direct support, such as mandatory purchase of regionally produced components, financial and tax incentives (manufacturing components), export assistance, R&D, and instruments to facilitate commercialization (i.e. pilots, demonstration, trade missions). 'Indirect' mechanisms favour market pull to induce demand via FIT and mandatory renewable energy grants (Renewable Portfolio Standard -RPS quotas) explicitly included in long term energy plans and the FIT scheme. These measures were introduced in the regional wind plans based on competitive government tenders. This common normative framework resulted in a range of responses across Spanish regions with some favouring public procurement oriented instruments (i.e. government tendering and local content requirements) and others keen to improve the competitiveness of their domestic industries (i.e. R&D support and commercialization and internationalization tools). In fact, the technological maturity and the institutional change seem to evolve together with market characteristic across time.

The evolution of wind energy industry has been characterized by the increasing number and variety of activities within the wind energy value chain. The value chain is then composed by interlinked components aligned from wind turbine manufacture to energy distribution. These components can be decoupled in the different modular technologies related with energy system such as energy distribution, electronics, mechanical engineering and transport. A view on the Spanish wind energy sector[5] reveals that firms engage different activities along the value chain, and a significant part of them (36%) carry out more than one activity.[6] The addition of activities is based in the substantial gains from vertical integration but also from the use of knowledge and expertise in the area that can be recombined and applied in any stage of the sector supply chain.

This performance is not exclusive of big firms as there are a substantial number of firms associated with Engineering, Operation and Consulting that develop more than 2 activities. More specifically, by looking at the type of activities within the supply chain, the data shows that the number and type of activities has evolved over time according to the sector devolvement. The overview of general tendencies on activity developed by industrial sites (IS) shows a mayor increase in the total amount of IS between 2006 and 2013.

Table 1 Evolution of supply change activities by type of industrial sites

Type of industrial site	2006	2007	2008	2009	2010	2011	2012	2013	Growth rate 2006-13
Assembly and logistics	13	5	18	24	25	26	26	29	123%
Blades & Control Systems	12	15	16	12	20	19	23	27	125%
Maintenance		2		9	9	9	30	55	2650%
Multipliers/Gearbox	4	5	4	4	5	6	5	5	25%
Towers and mechanical components	3	16	24	25	27	38	37	41	1267%
Turbines, motors & electric components	3	9	14	16	16	17	21	18	500%
Total industrial sites	35	52	76	90	102	115	142	175	400%
Number of activities involved	10	14	20	26	27	28	29	30	200%
Total firms owning at least one	9	19	40	52	53	58	70	82	811%

[5] Preliminary list of firms (227) in the Spanish Wind energy sector(AEE, 2011)

[6] The identified activities are: Wind farm Developer, Wind turbine Manufacturer, Component Manufacturer, Engineering and Civil Engineering, Operation and Maintenance, Consulting, Finance and Insurance, Transportation &Logistics, Technology Centre, Training and Other.

HHI concentration index[7] - Firms ownership	0,37	0,20	0,10	0,03	0,06	0,05	0,03	0,03	-92%

Source: own elaboration based on AEE (2006-2013)

Interestingly, the rate of expansion of IS has not been affected by the economic downturn of the last part of the decade. Rather we observe two types of redistribution. First, the number of actors has outgrown the expansion of activities that each one engages, suggesting a turn towards higher specialization[8]. According to experts, this results has been part of the process of identified complementarities between different components as well as the search of opportunities to introduce incremental innovation through technologies already in the traditional sector (i.e. power generation, materials, aeronautic) or adaptation of available technologies in the demonstration stages (Cano Santabárbara, 2013; Hurtado Pérez & Pérez-Navarro Gómez, 2013; Ugalde Sanchez, 2013)-

With that respect, the research activity has experience a significant evolution in the period 1995-2011 where the total budget for R&D activities present a significant growth (232%) while the budget increase for the research in the energy sector rise to and 382% (see figure 3) . This result implies that energy research has increase the participation as part of the total form 2.7% to 3.9% at the end of the period. More specifically, the performance of individual funding scheme for R&D projects can be described by the simultaneous performance in the Spanish National Research Plans (NRP), the applied R&D programs co-funded by national Spanish and European sources and the EU projects. With that respect, the figure 4 shows the evolution of number of project granted in energy related projects[9]. The data shows an inter-annual increase in the total amount of projects in the period 2004-2010, when data on NRP is available and reinforced the trajectory of the other sourced of funding. In the whole period the number of project granted has increased 403%.

Figure 3 Public R&D expenditure in Spain – Total and Energy sector

[7] Herfindahl–Hirschman Index is estimated trough $HHI = \frac{(\sum_{i=1}^{N} s_i^2 - 1/N)}{1 - 1/N}$ where s_i is the market share of firm i in the market, and N is the number of firms.

[8] This trend is also corroborated by the application of indexes to micro data from the panel of industrial sites. The Herfindahl–Hirschman Index (HHI) captured this diminution in the concentration of activities among firms by revealing a decrease of 92% in the whole period

[9] NRP and EU projects have been selected by applying content analysis techniques and keywords codification to the titles of projects included in the data set. CDTI projects have been provided by the national agency by filtering according UNESCO codes related to the wind energy sector.

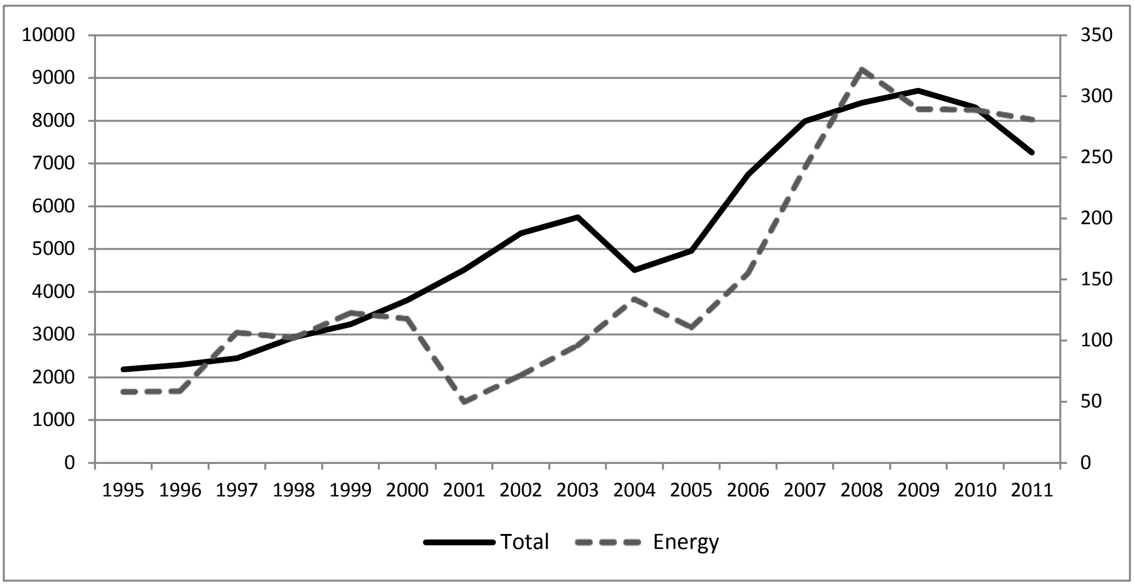
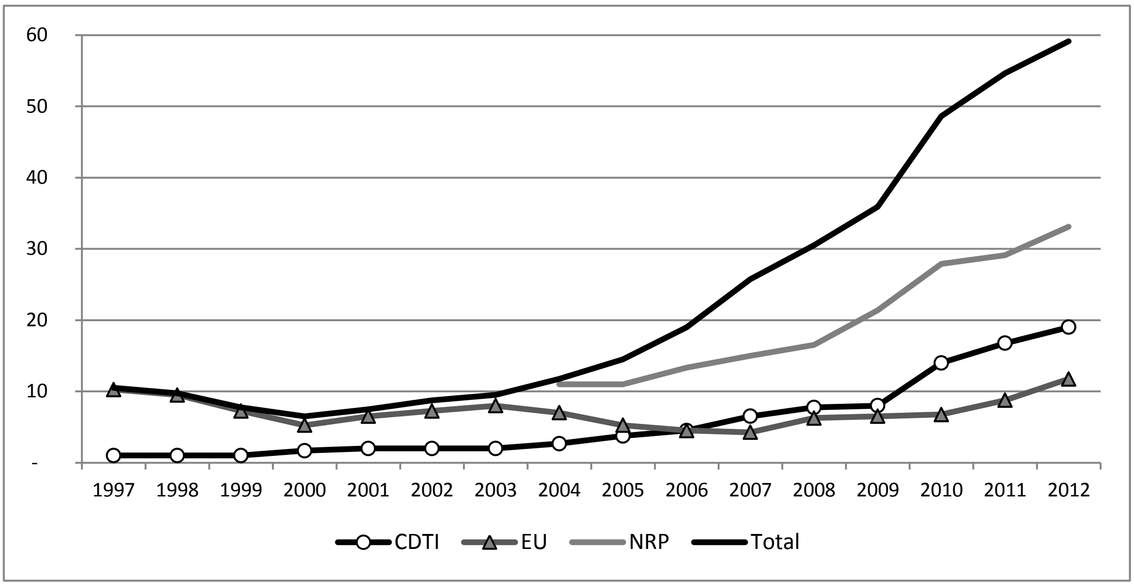


Figure 4 Total number of Wind energy related project granted in Spain per year by source of funding



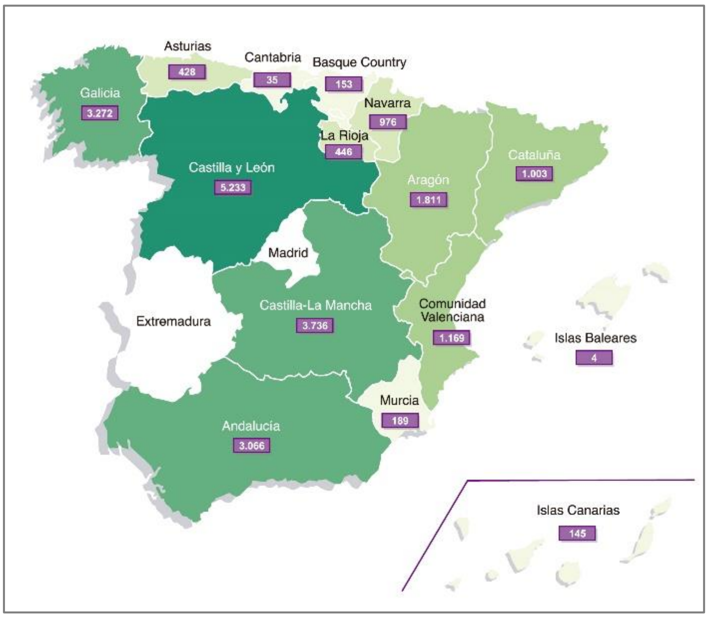
Source: own elaboration based in several data sources(CDTI, 2013; CORDIS, 2013; INE, 2014; MINECO, 2013)

Research activities play a fundamental role in the maturity of wind energy turbines by enabling better interoperability across components of wind farms and higher efficiency. The Research capacity depends on the presence of specialized infrastructure for R&D in regions, however, which can significantly differ from the distribution and evolution of industrial capacity as well as the availability on natural resource. With that respect, the regional dimension on the development of Spanish wind energy sector is explained as follow.

3.2. The regional setting and industrial history

The wind energy production in the Spanish regions is determined by the distribution of installed capacity which follows the logic behind the natural potential: availability and quality of wind resource[10]. Thus, wind potential is related to the geographical conditions which favors the concentration of wind energy capacity in regions combining largest areas and performing well in wind quality indicators. From this, four categories can be identified then from the final distribution of wind energy capacity measured in MW: 1) the leaders: Castilla y Leon (5233 MW), followed by Castilla- La Mancha (3736 MW), Galicia (3272 MW) and Andalucía (3066 MW), 2) Medium capacity: regions between 1000MW and 2000 MW as Aragon, Valencia Region, Cataluña, and Navarra, 3) low and none capacity: other regions few or non-capacity (See Fig. 5)

Figure 5 Wind power capacity in Spanish Regions (MW) 2011



Source: own elaboration based in REE (2013)

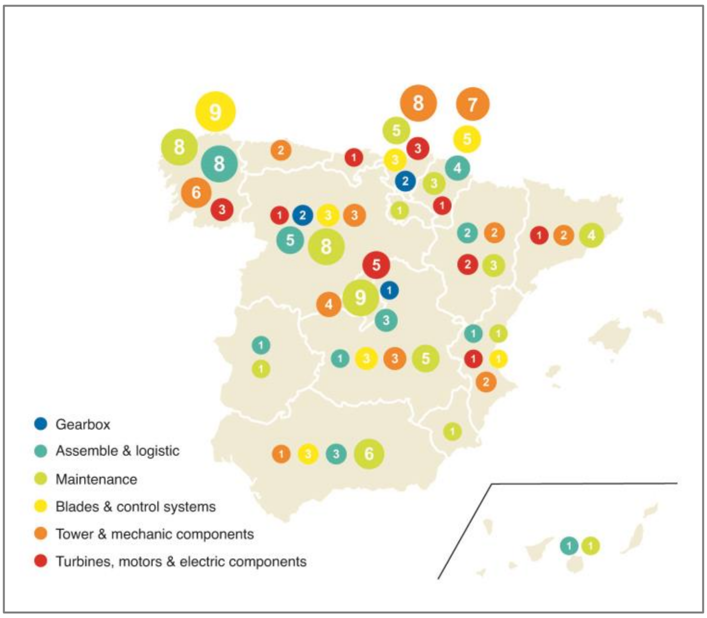
Behind this aggregate picture are differential patterns of local development. Clearly, regions leverage existing strengths along their inherited patterns of industrial and policy specialization. This entails the articulation of public and private stakeholders

[10] The natural resources is based in the availability (extension of technical available area) and quality (stability and speed) of wind. These two characteristics are the key indicators, thereby, wind energy capacity is then concentrated in regions combining largest areas and performing well in wind quality indicators. Then, wind can be measured by two linked indicators: 1) The extension of the area in which is technical available which basically refers to rural non populated areas and off shore continental platforms and 2) The wind speed that can be measured also by density. The study of Aeolian map of Spain (IDAE, 2011) indicated that the threshold for optimal operation is speed>6 meters per second at 8 meters high.

through the development of a spectrum of “innovative capacities” that relate to complementary spheres of intervention.

First we consider industry capacity, that is, the relative density of industrial centers as well as the availability of relevant competences for the deployment of production infrastructures. Figure 7 shows the latest snapshot of industrial sites divided by type of activity across regions.11 The evolution of this capacity has followed different trajectories. Until 2007 four autonomous communities accounted for 83% of industrial centers: Galicia12 (40%), Castilla y Leon (17%), Navarra (15%) and Castilla La Mancha (10%). More recently however the distribution of supply chain components has spread more widely with Galicia (19%), Castilla y Leon (13%) and Basque Country (12%) taking the leadership.

Figure 6 Wind power industrial sites 2013



Source: own elaboration based on AEE (2013)

These trajectories reflect the existing patterns of industry specialization. Since 2006, regional industrial capacity has grown not only in terms of local involvement in wind energy related activities, but also in terms of variety of actors involved in the supply chain. Interestingly, the rate of expansion of industrial sites has not been affected by the economic downturn of the last part of the decade. Rather we observe two types of redistribution. First, the number of actors has outgrown the expansion of activities that each one engages, suggesting a turn towards higher specialization. At the same time, activities are less geographically concentrated and, even though the historical

[11] Circles represent different types of industrial activities as per the color-coding; the figure in the circle is the total per region with size adjusting accordingly.

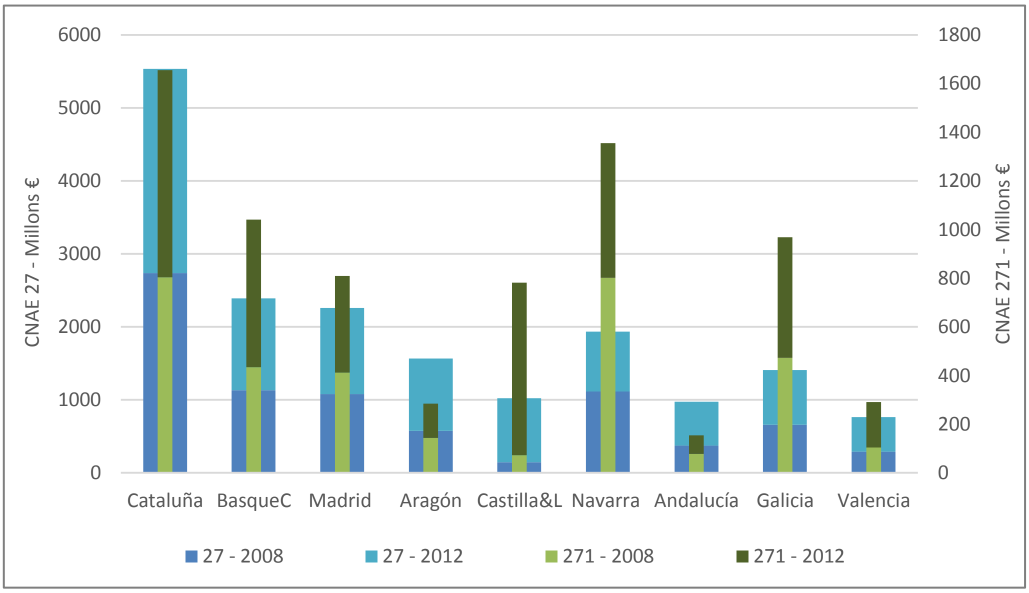
12 In 2007, industrial center in each of five big categories were operating in Galicia

leadership of regions like Galicia and Basque Country has not been undermined, formerly peripheral regions have entered the gravitas of the wind energy industry. This is rather common at mature stages of a technology's life cycle, when non-production activities acquire a bigger share, such as for example maintenance activities.

Furthermore, the industrial development on wind energy manufacturing has had an impact in the performance in external markets. Metallurgy (CNAE 24)13 and Machinery (CNAE 25) – the main subsectors - are dominated by Basque country, Cataluña and Andalucía while the sector with strongest linkages with renewables energy, manufacturing of electrical material and equipment (CNAE 27), is not significant in the general amount by comparing with the main ones. This sector follows the same positioning among leading regions, however, the data disaggregated at 3-digit for the category Manufacturing of electric motors and generators (CNAE 271), revels a different performance at general level and among regions (see Fig 4).

The exports of CNAE 271 shows a growth rate over the average (250%) for the period 2000-2013 leading by Cataluña, Basque Country and Madrid, however, Galicia, Castilla y Leon and Navarra shows outstanding growth rates and uptakes significant positions. The trajectories of the new comers have change significantly in the period 2004-2010 - a period of strong financial stimulus in the internal market by the feed-in tariff scheme - when Cataluña keeps the leading position; Navarra got the second position, Basque country keeps the third and Galicia and Castilla y Leon get the fourth and fifth place by leaving behind Madrid which use to be in the third position.

Figure 7 Evolution of Exports CNAE 27 & 271. Main Spanish regions 2008 & 2012



Source: own elaboration based in (DATACOMEX, 2013)

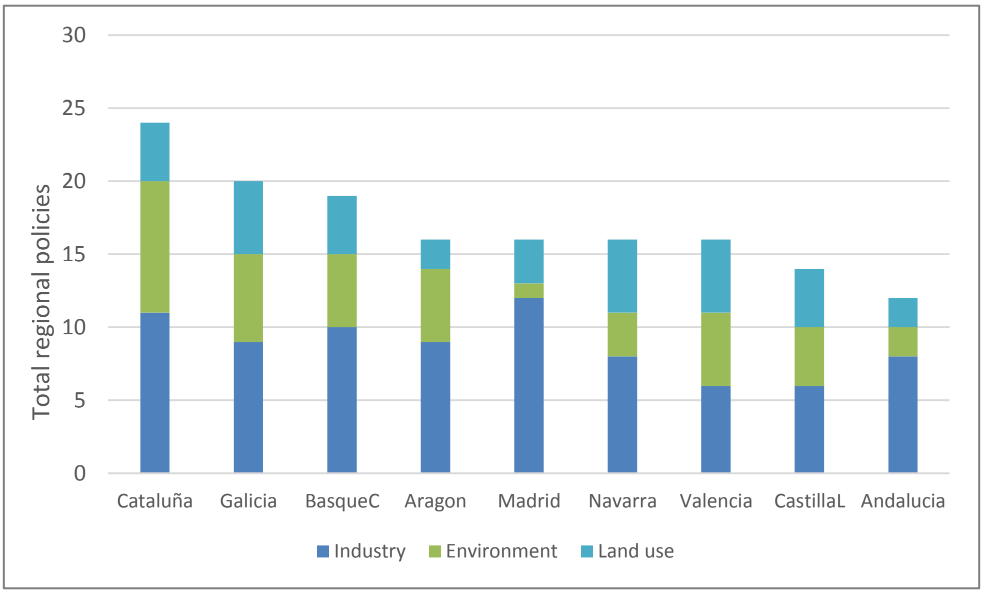
[13] CNAE: National Classification of Economic Activities

This result is relevant because it reveals a significant improvement in the performance on manufacturing competences of leading regions in the production of wind energy through better positions in the commercialization of RREE related technologies in external markets. These linkages between energy production and home market deployment can be found in the development of regional strategies. In fact, main regional differences in those linkages are associated to the relation between energy production and manufacturing of energy technology which determine the organizational features of the whole value chain.

With that respect, the organizational capacity of the wind energy sector relies regionally in two aspects: first, the way each regions applies their competences on set of energy, industrial and environmental normative and second, the existence of actors with dominant position located in the region or with rights to exploit their technology and services. The main regional policy interventions in the wind energy sector are addressed through the regional industrial plans, which give right to do research, produce and exploit development on new emergent sectors (i.e. RREE) and, the wind plans as long term planning that confer rights on the exploitation of technical areas for wind energy production.

By 2010 the 50% of renewable energy related policy at regional was related to industry regulation while the rest was divided in similar share between environment and land use (Fig 5). The regions presenting the mayor amount of normative are Cataluña Galicia and Basque Country but they have also have performed a long and stable trajectory on the introduction an implementation of normative for renewable sector. In the other hand, the first regions introducing wind energy plan were Galicia, Navarra and Aragon. With that respect, the wind plans have been a way to foster interaction between government and private actors towards o possible interlinked strategies: home market deployment or industrial development.

Figure 8 Distribution of regional policies on RREE according to main categories. 2010



Source: own elaboration based in (MIETUR, 2010)

The wind plans includes formal long term agreements by inserting commitments and rights on the exploitation of wind resource which set the bases for the coordination between regional governments, utilities and manufacturers. By doing so, the regional movement encompasses different pathways regarding the management of resources and decision making mechanism which may be characterized by centralized of decentralized models. For example, the business model for the regional exploitation of resources may be designed to favor either the participation of main regional companies or more entrepreneurial initiatives as Independent Power Producers -IPPs- (see Annexes Box 1) and local public-private management of wind farms. Regarding the first option, the existence of a simultaneous set of industrial policies (e.g. long term policies supporting manufacturing related sectors) can influence stronger developer-manufacturer linkages as well as the broader variety of industrial actors in terms of size and position in the supply chain.

Both interventions are designed and implemented jointly with the purpose of establish special arrangements on collaboration between the beneficiaries of industrial plans (manufacturing firms/wind developers) and the beneficiaries of wind plan as utilities and independent power producers (IPPs). Thus, most of interactions between firms such as collaboration between large companies and SMEs as well as intra-sector collaborations are determined by these instruments; therefore, the structure of the regional market may vary depending of different policy strategies and the industrial concentration.

The performance of developers and wind turbine manufactures reveals a pattern of concentration among utilities and main manufactures[14], however, the performance among regions shows a significant level of concentration in both wind turbine manufacturer and developers/utilities. Regarding energy producers among leading regions, small IPPS and developers hold the mayor part of the markets of Castilla y Leon and Andalucía while Galicia and Castilla -La Mancha shows a strong presence of big players (i.e. Iberdrola and Acciona). On the other hand, the markets of regions with middle and low power capacity are mostly covered by small and individual developers. The exception is Navarra where Acciona holds the 62% of the market. This result can be explained by the territorial distribution of market competences among utilities companies in Spain.

Regarding the wind turbine manufacturer, the performance at regional level is not homogenous. By looking at the distribution of wind turbines among main regions and

[14] Data on aggregated Spanish wind energy market (AEE,2013) for 2013 shows that 51% is distributed among the big Utilities (Iberdrola, EDPR, Enel green power and Union Fenosa) and Acciona as a top IPPs and, the other 49% is operated by other/small developers. Regarding manufactures of technology, leading companies Gamesa and Vestas hold 67% of the total market

wind turbines manufacturers (Fig. 9) two main results can be identified. First Gamesa got 50% of the Spanish market, a clear predominance in the big regions as Castilla y Leon, Castilla La Mancha, Andalucía and Galicia as well as lower (but significant) share in the other regions. The second issue is related with the performances of “other” manufacturers which present higher shares in the smaller regions. This result can be partially explained by the government owned and experimental nature of many wind parks in less develops market as Canarias and Balearic islands. The Figure 10 indicates the Herfindahl–Hirschman Index (HHI)[15] concentration index based in ownership of wind farms at regional level. The index confirms the results presented in the chart for the full list of regions.

Figure 9 Market concentration in the Spanish wind energy market. Main actors

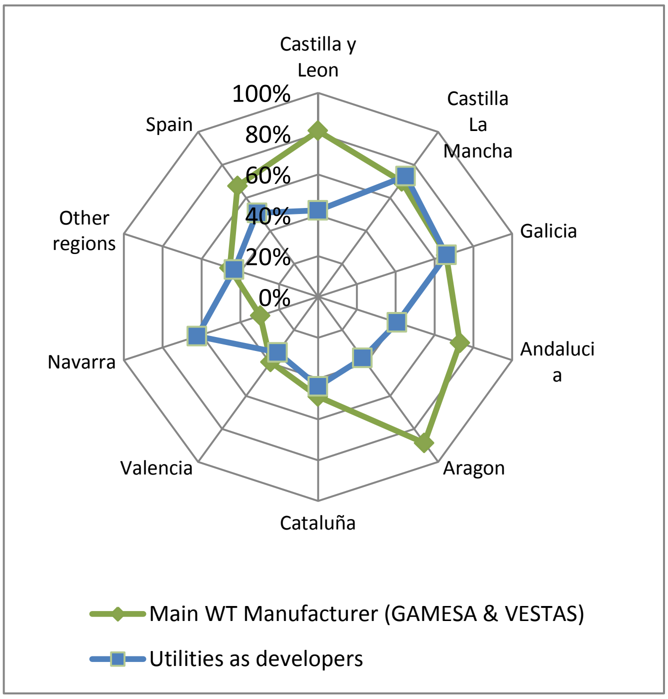
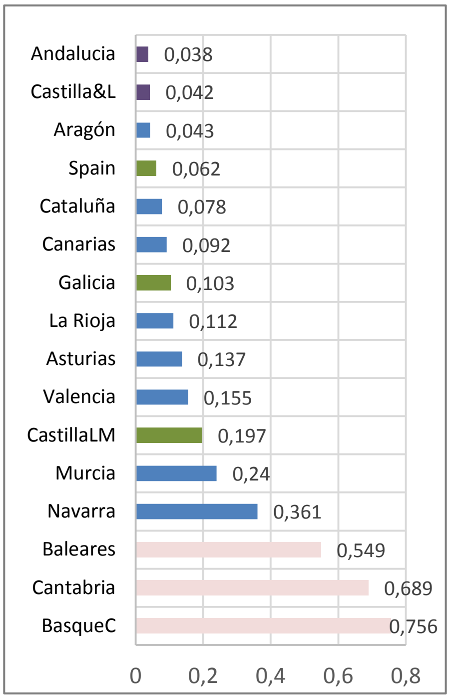


Figure 10 Concentration of wind power capacity at regional level.



Source: own elaboration based in (AEE, 2013b)

To sum up, Spanish regions present competences in key sectors related with the technological aspect of wind energy as Metallurgy, Machinery and Electric equipment. Some of these regions have a long tradition in the area (ie. Cataluña, Basque country, Navarra) and became participant in the renewables energy sector more recently. Other regions with smaller economic as Galicia, Castilla y Leon and Castilla La Mancha with similar knowledge base in technological areas has increasingly develop competences and specific industrial infrastructure for the wind energy sectors. These

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[15] Herfindahl–Hirschman Index is estimated trough $HHI = \frac{(\sum_{i=1}^{N} s_i^2 - 1/N)}{1 - 1/N}$ where s_i is the market share of firm i in the market, and N is the number of firms.

advances have created strong linkages with the energy sector but also the explotation of opportunities for commercialization of new technologies in international market.

The alignments between technology manufacturers and energy producers, strongly facilitated by regional governments, seem to be a key element in the creation of regional paths for developing a new sector where both local market opportunities and industrial development are complementary. However, further analysis on the location and performance of regional knowledge infrastructures should be done to identify the possible interdependencies with the location of industrial activities in order to provide better evidence for a better understand of internal and extra regional complementarities.

3.3. The knowledge resources and research capacity

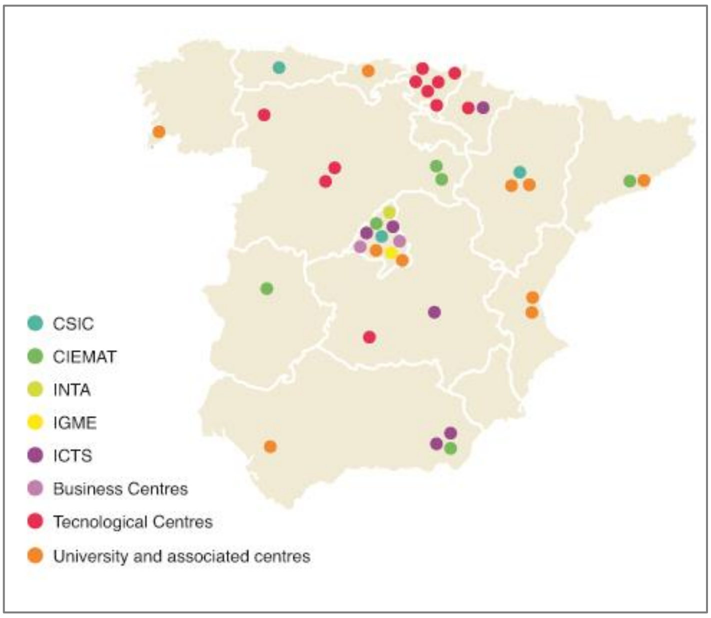
The regions provide a governance structure in term of public and private organizations that support the innovation through multilevel and multi-sector linkages. The connections between the location of industrial activities and regional knowledge infrastructures are critical to explore internal and extra regional complementarities on knowledge bases and competences. Furthermore, the emergence of a new technological field can be based in the adaptation and modular recombination of existing traditional knowledge available in both knowledge institutions and industrial sectors (Asheim & Coenen, 2005; Consoli & Patrucco, 2011; Gawer, 2010) .

In Spanish regions different indicators reveals some patterns in the performance in R&D activities. For example, as mayor economies, Madrid, Cataluña and Andalucía presents the mayor R&D expenditures in the last decade, however, the mayor relative increase has been experienced by Navarra, Basque Country and Castilla and Leon. Research capacity in renewables energy depends on the presence of specialized infrastructure for R&D in regions. Notwithstanding the maturity of wind energy turbines, research activities play a fundamental role in enabling better interoperability across components of wind farms and higher efficiency. In Spain four regions hold the lion share of research infrastructure (63%), namely Madrid, Basque country, Castilla y Leon and Andalucía. The Basque country, in particular, is host to the majority of technological centers while the other regions exhibit greater variety for what concerns research infrastructure (Fig. 11).

Basic research data shows an inter-annual increase in the total amount of projects in renewables energy related areas during the period 2004-2012 wherein universities are the main actors and Madrid, Andalucía and Basque country are leaders. For what concerns applied R&D programs the Basque Country and Navarra perform much better through intensive collaborations with universities (41%) and technological centers (36%). It is important to stress that strong industrial leadership easily translates into either strong market deployment, as in Galicia and Castilla y Leon, while a strong R&D

orientation, such as that of the Basque country, Navarra and Madrid, opens up global markets opportunities. That is to say, capacities influence each other (Table 2).

Figure 11 Energy research specialized infrastructure 2013



Source: own elaboration based in (López & Moliner, 2012)

Table 2 Distribution of wind energy related R&D projects. *Spanish Regions 1980-2012*

	R&D CDTI	EU	NRP	Total	Share
Madrid	15%	54%	32%	110	23%
BasqueC	41%	41%	17%	70	15%
Cataluña	7%	56%	38%	61	13%
Andalucia	16%	23%	60%	43	9%
Navarra	63%	19%	19%	27	6%
Aragon	36%	23%	41%	22	5%
Valencia	6%	31%	63%	16	3%
Castilla&L	46%	15%	38%	13	3%
Galicia	9%	36%	55%	11	2%
Other	12%	39%	49%	98	21%
Spain	21%	41%	38%	471	100%

Source: own elaboration based in the following sources (CDTI, 2013; CORDIS, 2013; MINECO, 2013)

Finally, regarding the participation of Spanish actors in European collaboration projects related to wind energy, the data obtained from the EU dataset CORDIS shows an increasing participation in the total number of projects[16]. The leading regions in this sample Madrid (25%), Basque country (16%) and Cataluña (13%) follow the pattern described in the other programs.

To sum up, the overview of knowledge resources at regional level confirms that mayor economies concentrate most of R&D activities, however, when most specialized infrastructures are considered Basque Country (a region with strong industrial capacity on wind energy technologies) and Castilla and Leon (the leader in wind power capacity) achieve better relative positions. Thus, there seems to be a confirmation of the linkages between the density of specific R&D infrastructure in the area of renewable energy and the location of industrial activity. On the other hand, regarding research performance leading regions in the energy production do not perform well in term research outputs, however, regions with strong industrial capacity as Basque country and Navarra has reached significant results in university- industry collaboration. Finally, Madrid is an archetypical case that may be operate as a regionalized national innovation system (Asheim) since its cover most of the institutional and industrial elements linked to the national and international innovation system.

The data on R&D performance shows some linkages between knowledge resources and industrial infrastructure, however, there is still missing a better explanation on the way of the existence regional knowledge bases interact with the industrial regional setting to foster the creation of an emergent new sector. At the same time, the implementation of regional strategy by combining a set of industrial and energy policy determine a variety of regional environments for the development of the wind energy sector. Thus, in order to provide a better explanations on the pattern of regional specialization, three regions (Galicia, Castilla y Leon and Basque country) will be further analyzed with additional evidence gathered from regional documents an interviews. This regions are example of different strategies in the use of the regional resources in the search of pursuit two objectives: home market deployment and technology development.

4. Three tales of regional specialization

The pathways of specialization has been already analyzed by focusing on the generation of production capacity (energy production) and the implementation of R&D activities by combining regional knowledge resources against the specificity of regional backgrounds such as industrial history and research capacity. These pathways have been facilitated by the regional industrial setting combined with a wide mix of policy instruments. Taking these dimensions as key constructs we identify three paradigmatic

[16] The projects in the chart were obtained by applying content analysis on the abstract and the title. A set of key words related to wind energy technology has been applied for that purpose.

pathways of regional development, namely Galicia, Castilla y Leon and the Basque Country. These cases provide a wide perspective on the diversity pathways towards sectoral specialization. The following analysis will highlights critical actions, their evolution and the relative positioning of each region within a changing system of interactions.

4.1. Galicia

Galicia can be classified as an ‘early movers’ category, having pioneered the promotion of wind energy in Europe since the early days and having become a leader in installed capacity and industrial centers. The development of wind energy sector in Galicia was based in a regional strategy to foster renewables energy capacity while developing the industrial capacity in term of production of local components. The general background of this strategy was a set of national normative as the National Law 40/1994 on the restructuring on National energy system and the National Energy plan 1991-2000 which foster the development of renewable energy and establish specific targets on RREE quotas. Regionally, the initial milestone of this strategy is the introduction of sectoral regional plans in 1995 by which the regional government aimed to foster new industrial sectors. However, critical actors in the case of wind energy sector as ENDESA, IDAE and Ecotecnia had started conversations with the regional government much earlier regarding the exploration of significant Galician wind potential(FERREIRA, 2011; Ferreira & Garcia, 2010).

The Wind energy plan of Galicia was introduced then in 1995 by which the areas of exploitation were identified and the mechanism to assign the rights to develop wind energy capacity was presented. For doing so, the strategic wind plans (SWP) - later called business wind plans- were the main instruments (Carballido Roboredo, 2013). Land use and environmental protection normative has been introduced in the following years even behind the activity of developing wind capacity[17]. In that sense, the lack of specific normative on the analysis of alternative land use (ie. Forestry) was a significant driver to accelerate the wind exploitation by the implementation of SWP (Ferreira & Garcia, 2010).

The general design of the SWP includes a set of right and commitments for the holder regarding the development of infrastructures and the use of energy potential in the selected areas[18]. Regarding commitments, the SWP have to carry out research activities on wind energy and transfer the results to the regional government, develop

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[17] The 90% of SWP were assigned between 1995 and 2001 (Muñoz, Fernández, Fernández, & Rodríguez, 2010)

[18] These rights were entitled as “preferred” under the first normative of 1995 but turn to “exclusive” since the appearance of new normative in 2001.

a specific amount of wind energy capacity and execute an economic investment on components and technologies. Regarding this last, a specific share of the total investment should be associated to Galician firms but the share of wind turbine components is specified within the amount of investment in Galician firms (Miguez et al., 2006). Additionally, SWP holders were responsible for deliver industrial plans - developed by their own or with third parties- with the purpose of foster new industrial activities and support the development of photovoltaic industry.

Some SWP holders designed and implemented their own industrial plans to face the commitment of wind technology components produced locally. The industrials plans include the industrial infrastructure required (owned or from other associated firms), the estimated employment and time planning as well as the specific the share of investment in Galician firms (average 80%) and the share of wind turbine components (average 65%)as part of the total investment (Muñoz, Fernández, Fernández, & Rodríguez, 2010). Finally, the new industrial capacity on wind turbines components created by these firms was also used by other SWP holder to achieve the required share of Galician investment.

Beside the SWP holders, other two types of actors can operate in the Galician wind markets. First, private developers can access to market though operating just a single wind park and second, private /public developers can have either and industrial or domestic use (e.g. co-owned by local governments) under the modality of Singular Wind Parks (SWP) which are aimed to generate energy for the consumption of their owners. This last category was valid just between 2001 and 2007. This categories has increased the variety of actors, however, by 2010 the wind capacity developed under SWP represent around 90% of total (Ferreira & Garcia, 2010; Muñoz et al., 2010).

The local manufacturing of components for the development of wind capacity was based in the different activities proposed in industrial plans carried out by the SPW holders. The local metallurgic industries got a new market regarding wind turbine frames while in the first stage the mayor technological components were produced outside Galicia, however, during the period 1995-2007 industrial infrastructure on assemble, blades , towers, materials and maintenance were develop by Danish companies as LM and Spanish companies as Gamesa and Acciona[19] (Muñoz et al., 2010). By the year 2007 the industrial infrastructure had increased considerably to provide technology for emergent market when Galicia got 21 industrial centers, the 40% of total for the Spanish sector (AEE, 2013a).

To sum up, the regional strategy to foster the wind energy sector in Galicia was based in tow pillars. First, the Galician normative establishes specific investment in Galician

[19] Gamesa was part of joint venture with the Danish company Vestas from 1994 to 2003 whole Acciona has developed its own technology in collaboration with other companies but it increased its industrial capacity by acquiring Ecotecnia in 2003.

firms with the purpose of manufacture wind turbine components locally. Second, SWP holders which have implemented industrial plans has provided technology for their own wind parks and for the wind parks of other SWP holder without industrial capacity since 1995. These two factors have been critical for the evolution of Galician industrial capacity and the market configuration in term of develops-manufacturer relations[20]. These two pillars have then pushed the significant growth in wind power capacity and, thereby, transformed significantly the energy balance composition (IGE, 2014; INEGA, 2014). On the other hand, the trajectory of the energy sector move simultaneous to the creation of new firms and industrial infrastructures based in the requirements on the use of comments manufactured locally have boosted.

4.2. Castilla y Leon

The early stage of development of wind energy in Castilla y Leon was guided by long term planning on the energy sector. The region can be considered as a "smart implementer" in term of its performance as the runner-up region for density of installed wind park capacity and industrial centers even when it started with a relative disadvantage (i.e. a less developed industrial sector) but has over-performed several other Spanish regions.

The Regional energy plan for Castilla y Leon 1995-2000 introduced lines of action in different aspects such as energy saving, cogeneration and renewable energy. According to official documents, the main objectives, actions and initiatives were based in early experienced of other Spanish regions but also by following actions started in 1989 as part of renewable energy programs at national and European level (e.g. Valoren, Plan for saving energy efficiency PAEE). The development, coordination and implementation of those initiatives relies on the regional energy agency (EREN) but decentralized at provincial level.

More specifically, the actions on the wind energy sector were early established in 1997 by the introduction of normative on the regional renewables energy targets for 2010 and the regulation for the development of wind parks. In 2001, the Regional wind plan for Castilla y Leon was introduced by emphasizing the role of provinces in the implementation process (Ciria, 2012). The industrial plan considers a series of stages as time sequence for the implementation in each province. The basic structure of the plan is formed into two main parts. At first, the number of facilities, features and

[20] The market present a significant level of concentration in the wind energy production as 2 developers (Acciona and Iberdrola) out of 72 got 39% of the total number of wind parks but 50 (69%) developers own just one wind park and 15(20%) got two. Regarding wind turbine manufacturer, the concentrations even higher as only one provider, Gamesa-MADE, got 43.8 % of the Galician market followed by international providers: the Danish Vestas, the German Siemens and the French/Spanish Alstom-Ecotecnia.

locations are defined and, in second place, the industrial, technological, socio-economic and business development is described and explained.

Other secondary instruments for supporting wind energy were a grant scheme for small scale wind turbines which was based not only in the security of supply of isolated places but also in the potential of the advances of this technology (i.e. Vertical wind turbines). The regional government also facilitates a series of installations for experimenting with new technology not yet prepared for the market stage.

The regional government has set the priorities on manufacturing locally most of the wind turbines installed in the region though the introduction of mandatory purchase of regionals components through the connection between Wind Plan and Industrial plans. The regional strategy is aimed to impulse investment and employment by seeking around 85% of components manufactured locally. More specifically, the regional government has signed commitments with top wind energy manufactures (Made, Nordex, Enron, Ecotecnia, Neg-Micon, Gamesa, LM Composites) which has installed industrial facilities on components manufacturing (e.g. blades, towers, machinery)and assemble and logistic centers (CECALE & IDEM, 2002).

The result of this strategy has been the not only the significant growth of wind power capacity (from 28,7 to 5505,1 MW) and energy produced (from 32,06 to 5059 GWh) in the period 1998-2013 but also the expansion of wind energy related industrial centers in Castilla y Leon. As it has been presented before, the number of industrial sites has increased from 8 to 22 to in the period 2006-2013. Most of these infrastructures can be associated to the original industrial plans promoted from the regional government which according to EREN (González Mantero, 2008) had generated 3.500 jobs by 2008 in industrial areas such as Blades, Brakes, Components manufacturing, Electrical components, Metallurgy, Multipliers, Nacelles, Towers an mechanical components, as well as Wind turbine assembly and manufacturing.

The perspective of regional government is based in the assumption that the wind turbine manufacturing companies are mostly big companies that shares 30% of the industrial structure. In this line, the other 70% of companies are SMEs that develops activities on engineering, installation and wind farms developing (CECALE & IDEM, 2002). Thus, from regional perspective, the new industrial installation may be benefited from further exploration of related industrial sectors (no exclusive for wind turbines) as machinery, naval and aeronautic industries but also the search of new external markets on wind turbines in specific sector.

4.3. Basque country

The Basque Country (BC) is our third case study. Placed at the bottom of the list for wind energy production, it is the third region in Spain for number of industrial centers and the second for number of R&D centers specialized in energy issues. The BC region has a long trajectory of R&D programs oriented to integrate industrial research and experimental development, as well as a proactive regional strategy. Given this particular profile, Basque country has been labelled as the “knowledge creator”.

The initiatives to foster wind energy in Basque country began in 1984 with a program to explore opportunities related to small wind turbines. In the following years, the regional government introduce Energy strategies as long term programs seeking to set the RREE as a priority. In order to highlight that priority, the regional government created in 1996 a state-owned company -Eolicas de Euskaki- with the participation of Iberdrola[21] but became fully owned by Iberdorla in 2007 when the government decides to let development issues to private sector (Boveda, 2013a). However, in spite of the efforts of regional government running initiatives to support wind energy the target proposed in 1997 for 2005 was not even achieved by 2011. According to the Energy agency of Basque Country –EVE-(Boveda, 2013b), the reason behind the lack of success in the attempts to foster wine energy capacity relies in the delay in the presentation of the Sectoral Wind Plan in 2005 which establish the technical available areas but mostly in the barriers for its implementation. The main barrier was the low acceptance of the technology at regional level represented at first by environmental groups.

The initiatives on technology demonstration and the participation of the government in the sector finally got the acceptance of civil society; however, the implementation process was stopped by representatives at provincial level. Some of the provinces refused to continue after the first initiatives but other provinces have not accepted at all the development of wind infrastructure based on environmental criteria, aesthetic issues and alternative use of land. According to EVE (Boveda, 2013b), the current strategic energy strategy is looking for using the advances in new technologies manufactured regionally in the implementation of local wind capacity. However, the changes in the national normative context do not provide a proper environment.

The regional government got an early concern about the limitation (i.e. natural resource and social acceptance) to exploit the wind energy market so, emphasis was put in the development of technological capacities of the manufacturing sector by supporting R&D and internationalization activities. The policy instruments focus in the development of such industrial capacity that can follow the dynamic of international trends and exploits external market opportunities. The table 25 below describes the main instruments and areas of action of the policy portfolio.

Table 3 Summary of regional policies to support industrial development – Basque country

Policy instruments	Strategic projects	Strategic research projects	Experimental projects	Process innovation	Innovation in products and services	Organizational and market innovation	Training

[21] The company is responsible of the current four wind parks in Basque country

Lidera							
Etortek							
Etorgai							
+Innova							
Gaitek							
ALDATU							

Source: own elaboration based in (Parrilli, Elola, Alvarez, Lorenz, & Rabellotti, 2012)

The characteristic of this instruments regarding being strategic or experimental is related to the priorities of regional government in terms of industrial development. In that sense, most of those instruments- including the R&D based Etorgai, Etortek and Gaitek - are designed under non-recoverable subsidy modality. According to EVE (Boveda, 2013b), projects on improvement of wind turbine components, management and monitoring as well as control and preventive maintenance of wind parks has been funded by these instruments; however, during the last years those instruments were applied to projects on big wind turbine and offshore capacity.

The recent evolution of the wind energy value chain in the Basque Country has determined a more significant focus on internationalization of the production as well as the search of transformation within the value chain in order to get competitive position in external and global values chain. The movement can be related to and strategic response to the slowdown of local onshore market, the rising of external offshore market and the evolution to modular and relational technologies (Parrilli et al., 2012). In fact, the offshore market is highly supported by regional government through the development of a maritime experimental platform to provide infrastructure for experiment on different RREE technologies. Initially, experiments on wave technology will be run but it is planned to be used for the several ongoing R&D projects on floating platforms for offshore wind energy developed by Iberdrola, Gamesa, Acciona and Tecnalia.

5. Conclusions

The empirical evidence on the study of Spanish regions through the analysis of their industrial setting and processes of knowledge creation has revealed different trajectories in the wind energy home market deployment and the development of wind technologies. Moreover, regions with significant developments in technology production have revealed good results in the commercialization of related technologies in external market. On the other hand, a deeper analysis on the knowledge resources at regional level has provided evidence of a clear geographical concentration of knowledge infrastructures in leading regions which have performed well in research activities related with the application of different type of knowledge.

More specifically, regarding the industrial development and wind market deployment, the empirical evidence found in benchmarking exercised reveals differences in terms of competences for technology manufacturing and patterns of specialization in the wind energy production. In fact, all the regions with high specialization in wind energy production have developed relevant competences for the deployment of production infrastructure. Different regional policy strategies have facilitated not only the linkages across the value chain but also different forms of internal organizations. For example, the managing of government tendering of technical available areas affect the operation of Independent IPPs may varied between the ones that have capacity to operate and manage a large number of wind farms and the other ones may be operators on single or few number of wind farms. Castilla y Leon and Castilla La Mancha, the most specialized regions, have got the lower levels of firm's concentration among wind developers. Navarra and Galicia concentration is more significant which can be explained by the territorial distribution of market competences among utilities companies in Spain. Beside the different strategies, the four cases are considered fully integrated regions.

Regarding the search of knowledge complementarities, the evolution of competence in production infrastructures has been characterized by two main factors. The increasing number of activities associated to industrial infrastructures and the improvements in the regional performance in related industrial categories (i.e. CNAE 271 manufacturing of electrical material and equipment). Regarding production capacity, the number of actors and regions has evolved simultaneously with the variety of activities. Regarding the external market, regional differences has been found in the related variety index associated with exports on Metallurgy, Machinery and Electrical components. Finally, when knowledge resources at regional level are considered, the benchmark confirms the positions of Basque country and Madrid as leading regions in research. The same results can be found in the comparison of applied-research projects and the ones granted under EU funding schemes.

Some patterns of regional specialization are defined by natural resource endowment (i.e. wind availability and technical available areas), the differences in the regional industrial setting and the infrastructure and dynamics in regional process of creation and application of knowledge. By comparing and contrasting the experiences of these three regions, the present study has also provided new understanding on the dynamics of smart specialization by focusing on the evolution and change of regional innovation policy. We propose to focus on the policy mix that has allowed the three regions, in different ways, to coordinate multiple objectives such as: security of supply, environmental commitment as well as local support for the creation of new markets and the industrial sector. In so doing the paper has contributed to a better understanding of which policy agendas and instruments for implementation are favoured or constrained by institutional path dependency.

To sum up, the creation of pathways involves the combination of different capacities that influence each other. Regional strategies then will have an internal logic that produces impacts in the activities of actors and sectors depending on the regional setting. More specifically, strong industrial leadership easily translates into either strong market deployment, as in Galicia and Castilla y Leon, while a strong R&D orientation, such as that of the Basque country, Navarra and Madrid, opens up global markets opportunities. Finally, it is important to consider that the preceding analysis has not covered the inter-regional pattern of collaboration, knowledge and technology flows. Thus, the complementarities among regions should be considered as a potential factor in the creation of regional pathways.

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7. Annexes

BOX 1: Organizational Ecology in the Wind Energy Value Chain

The European wind energy value chain includes Utilities, Independent Power producers (IPPs) and Developers.

Utilities are the traditional players of energy sectors. They usually engage activities all along the value chain, including the generation, transmission and distribution of electricity in highly regulated markets. Depending on the competitive conditions and the regulatory framework, Utilities can take various organizational forms: investor-owned, publicly-owned, cooperatives or nationalized companies. Owing to increasing market liberalization and to the cost advantages of delocalization, some utlity companies have moved away from the established model of vertical integration and adopted mixed forms that entail limited participation in specific segments of the value chain. In some cases Utilities operate as brokers that buy and sell, rather than producing, electricity.

The other class of important players in the renewable energy market is that of **Independent Power Producers (IPPs)**. These can take the form of small facilities, large corporations or cooperatives. Their business is regulated by long-term price guarantee schemes such as feed-in Tariff or Power Purchase Agreements. IPPs emerged as a result of a wave of deregulation in the early 1980s in the attempt to reduce the market power of incumbent Utilities. The advent of IPPs has changed the logic of competition. These organizations are extremely adaptive and can either compete by developing, owning or operating wind farms. IPPs are often early adopters of new technology and early entrants in niche markets, and promote the mobilization of local competences and the reconversion of existing industrial capacity. This is the case of Spain where IPPs in wind energy have drawn heavily from the installed base of skills in the construction and other large-scale industries. There are two main types of IPP in Europe. **Integrated IPPs** have competences across the entire value chain and retain high control of all operations within the portfolio. On the other hand, IPPs can also operate as **Wind Project Buyers** not directly involved in the development of wind plants but rather as coordinators of a platform of independent part producers. This strategic route has brought about variety in the spectrum of relevant knowledge no longer limited to technical expertise on wind turbines but also including managerial expertise and financial literacy.

The last group of actors in the value chain includes **Developers**, that is, firms that engage activities involving the deployment of a wind farm, namely: purchasing or leasing the land, installing equipment to quantify wind currents, securing transmission, power sales, turbine supply, construction, and financing agreements. Some large developers occasionally operate entire wind farms, or evolve into proper IPPs, though the vast majority lack the operation capacity and the financing and will limit themselves to develop parts of a project before selling to larger companies.