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A REGIONAL ANALYSIS OF RENEWABLE ENERGY PATENTING IN ITALY

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A regional analysis of renewable energy patenting in Italy

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Abstract. The paper investigates the mechanisms of induced innovation in the renewable energy industry in Italy. Descriptive analysis reveals a decoupling of innovation and production: significant RES-related innovation in Northern Italy, high levels of renewable energy production in Southern Italy. A panel analysis from 1997 to 2007 for the 20 Italian regions reveals that renewable-specific local public R&D expenditure is the main determinant of the renewable energy patenting pattern. Local financial incentives play a significant, but less important role. The wind and solar sources depend more on local public intervention than other RES such as biomass. The development of RES innovation activities appears to depend also on the political orientation of regional councils, thus confirming prior research on the role of social acceptance and political support in the development of RES.

Research highlights. ▸ We describe regional RES innovation patterns observing a decoupling of RES innovation and production activities ▸ Public R&D grants are the main driver of RES patenting activities ▸ The impact of public incentives varies by type of technology, with highest effectiveness for wind and solar ▸ Political orientation acts as a inducing/hindering mechanism of patenting in renewable energy.

Keywords. Induced innovation, patents, regional analysis, renewable energy sources (RES), social acceptance.
JEL Classifcation. Q55, Q58, O34, O38

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Introduction

Earlier research on environmental knowledge creation was conducted following the Porter hypothesis (1991), according to which strict environmental regulation can encourage innovation and efficiency (Lanjouw and Mody 1996, Jaffe and Palmer 1997, Brunnermeier and Cohen 2003). Empirical studies focusing on renewable energies show that both domestic environmental policies (Popp et al. 2011, Johnstone et al. 2010b, 2011) and foreign environmental regulations (Haščič et al. 2009) constitute important drivers of patenting activity. Also consumer demand for environmentally-friendly products appears to be effective in inducing innovation (Popp et al. 2007). This has led to consider environmental knowledge creation as a borderless phenomenon. We believe, however, that RES innovation/adoption activities should be also analyzed at a local scale, in a context where natural endowments, environmental regulations, local incentives, and socio-political acceptance may act as inducing or blocking mechanisms for RES innovation activities. The link between geographic diversity and other local context variables and the pattern of environmental patenting at a local level is still understudied, and this work aims at contributing to fill this gap.

In this paper we consider the differences in the distribution of renewable energy innovation patterns across the twenty Italian regions and investigate whether the variability can be attributed to differences in local endowments or to institutional and socio-political variables. More specifically, we aim to establish whether there is evidence of induced innovation for RES in Italy, and to further investigate the extent to which social acceptance of, and political support to, renewable energy technologies contribute to RES patenting at the regional level.

Methodologically, we use a knowledge/ideas production function framework (Griliches 1986; Jaffe 1989) to model the relationship between innovative output, measured by the number of patent applications in renewable energy technologies, and knowledge generating inputs such as R&D expenditures, policy instruments and local context variables that can facilitate or hinder the development of RES. Our key results indicate that RES-specific local public R&D expenditures are the main determinant of the renewable energy patenting pattern. However the level of perceived legitimacy of the RES industry as a result of a favourable local political setting also plays an important role in determining the observed variability in RES innovation.

1. The local context for RES innovation activities

In our view a local scale analysis has a lot to contribute to understanding the dynamics of RES innovation activities. Factors such as natural endowments, national policies (emission regulations, RES incentives, R&D policies), and the local institutional, market and socio-political environment can act as inducing or hindering mechanisms and play a critical role in explaining the strength and diffusion of innovation in the field of renewable energies. Numerous previous works separately attest the impact of several of these variables.

Local endowments affect the distribution of renewable energy productive potential between and within countries (Musgrove 1987; Beyer et al. 1993; Asano et al. 1996). Geographic diversity significantly reduces the magnitude of extreme changes in the aggregated output of RES with high variability such as photovoltaic and wind, and hence the cost of managing that variability (Mills and Wise 2010). According to the literature, natural potential may affect not only the level of renewable energy production but also the related innovation patterns – RES patenting and adoption. Natural potential may act in both directions. On the one hand, when the technology required for the production of renewable energy is imported, it often needs to be adapted to a particular geographical context, thus generating a demand for local innovation. An example are the wind mills invented and produced in Denmark that, when installed in other countries, need to be adapted to the local wind intensity and variability. As wind power output is proportional to the cube of wind speed, the adoption of the traditional European turbines in India, for instance, would have been a failure if technology were not adapted so as to account for the lower intensity of Indian winds (Kristinsson and Rao 2008). On the other hand, countries well endowed in traditional energy sources will tend to have lower electricity prices and will be less motivated to invest in renewable energies. Large hydro power facilities and nuclear power, for example, act as substitutes for newer renewable sources and reduce the investments in RES (Popp et al. 2011).

Environmental policies are able to affect relative input prices and thus induce innovation. An increase in the opportunity costs associated with the use of environmental resources encourages technological change directed to economizing the use of these inputs. Emission control policies have been shown to work as a significant driver of environmental innovation among firms in Northern Italy (Mazzanti and Zoboli, 2009). Incentive packages for renewable energies may strongly reinforce these regulatory effects. Johnstone et al. (2010b), analysing innovation in the renewable energy field in OECD countries during the period 1978-2003, and controlling for the opportunities offered by fast-growing economies, for international legitimacy (ratification of Kyoto Protocol) and for substitute factor inputs (price of electricity), show that public policies such as feed-in tariffs and green certificates, rather than prices, are the main driver of innovation.

The effectiveness of public policies depends also on the level of public consensus for renewable energy sources. The level of consensus for the development of renewable energies has also been investigated by Bollino (2009) and by Bigerna and Polinori (2011) who, for the Italian case, estimated an aggregate willingness to pay in a range between 19% and 67% of the actual total public expenditure in RES subsidies. According to Wüstenhagen et al. (2007) mobilization of resources for RES turns around three dimensions, namely socio-political, community and market acceptance.

Socio-political acceptance is identified with the presence of effective financial schemes and spatial planning for RES technology adoption. This dimension was first described by Carlman (1984) who identified spatial planning of wind turbines as a matter of public, political and regulatory acceptance. Even if most of environmental standard setting takes place at a national or supra-national level (a preeminent role being played in Europe by EU directives), also sub-national governments play a significant role. In Italy, for instance, regions have the power to authorize or reject investment projects and to implement incentive schemes specific to the energy sector, such as subsidies on capital costs. Other financial schemes, conceived to stimulate entrepreneurial opportunities and collaborative initiatives, are sometimes translation of national calls into local ones.

Community acceptance refers to the involvement of stakeholders and residents in the implementation of renewable energy projects. Public perception of acceptability of a given technology within a given geographical and socio-economic context played an important role, for example, in the path of adoption of wind energy in Sweden. In the early 1970s Swedish proponents of wind power envisaged a potential production of 20 TWh, potential which was discredited by mass media who expressed distrust and characterized wind energy as "small" or "smaller than other electricity sources"(Jacobsson and Bergek 2004, Bergek et al. 2008). In the presence of uncertain signals, investors postponed the risky investments which lead to innovation: public perception became an obstacle to technology adoption and diffusion (Johnstone et al. 2010). Also the opposing behaviour of established energy suppliers, such as the hydroelectric and nuclear power sectors, and of substitute input suppliers, such as the coal lobbies, can hinder the development of RES technologies (Johnson and Jacobsson 2001, Popp et al. 2010). Conversely, positive expectations of technology adoption increase the mobilization of resources and the level of connectivity between actors of the technological systems and thus determine the inducement mechanism (Bergek and Jacobson 2003). For example, in Germany the first electricity feed-in law (1991) was an example of collaboration between local and federal politicians and the representatives of wind, small-scale hydroelectric plants and the farmers in north-west Germany. In that case, local Green party representatives succeeded in promoting local initiatives to the national level and environmental organization were included in the policy process (Janicke 1997). A conducive socio-political local environment was crucial to a development that was rather costly in the beginning (Breukers and Wolsink 2007).

Social acceptance and political support may also be acquired by complying with existing industries. In Sweden, for instance, wood ethanol and wheat ethanol shared the same downstream technology. As a consequence, wood ethanol suppliers had the support of agricultural associations and enjoyed the same tax exemptions and mobilization of resources thanks to the conformity with the pre-existing wheat ethanol technology (Bergek and Jacobsson 2008).

Market acceptance is related to the process of market adoption of an innovation through communication between individual adopters and their environment (Rogers 1995, Wolf 2007, Mallett 2007). Specific skills and perspectives contribute to the process of adoption of technologies (Lall 2004a, b). The level of technological advancement of the local industry as well as the presence of research centres and, more generally, institutions facilitating information exchange may contribute to determine localised patterns of RES innovation. Firms will agglomerate in areas where they find the knowledge and necessary resources to develop their innovative activity (Feldman, 1999) clustering in areas where the concentration of economic activities and the local stock of knowledge are higher (Autant-Bernard 2001). UK pioneers in the energy sector were from technical universities, engineering and construction companies (Breukers and Wolsink 2007). In Northern Italy cooperation between firms and local universities has been shown to be an important driver of environmental innovations (Cainelli et al. 2011).

Degrees of acceptance at different levels are interlinked. Socio-political acceptance fosters community acceptance. Public-private partnerships enhance the level of understanding of RES innovations and contribute to a higher diffusion. Together, socio-political, community and market acceptance contribute to the formation of a policy community for renewable sources, mobilizing actors and resources around renewable energies at the local and national level (Breukers and Wolsink, 2007).

2. Model specification

This paper's objective is to analyze in a structured way the link between the localization of innovative activity in the field of renewable energies and a number of local context variables. The conceptual framework is the knowledge production function used by Griliches (1986) and Jaffe (1989) to explain the emergence of innovations – a generalization of that typically used in endogenous growth models (Romer 1990, Jones 2000). The explanatory variables included in our model are presented in Table 1.

Table 1 Model variables

Dependent variable	
RES patents: Total, solar , wind and biomass & waste	
Independent variables	**Expected sign**
Public incentives from regional governments to RES production and innovation (million €)	+
Regional government political colour	+/-
General public and private expenditure in R&D (rate over GDP)	+
RES research funded by national government ((million €)	+
RES research funded by national government in physics (dummy)	+
Share of regional photovoltaic & wind power installed capacity (%)	+
Regional Growth of photovoltaic & wind power installed capacities (%)	+
Regional Growth of hydroelectric power installed capacities (%)	-/+
Net energetic imports (TWh)	+
Net energetic balance with other Italian regions (TWh)	+/-
Growth of regional electricity consumption (%)	+
'Objective 1 Regions' status (dummy)	-
Growth in average oil price (%)	+

In Italy, public policies supporting the creation and adoption of renewable energy technology are designed both at the national and local level and are often used in tandem. The most important measures implemented uniformly at the national level are *CIP6 (Interministerial Committee on Prices)*, *feed-in-tariffs*, *comprehensive fees (tariffe onnicomprensive)*, *Net Metering (scambio sul posto)*, *green and white certificates*, *high-efficiency cogeneration*, *tax deductions* and the *Revolving Fund for Kyoto*. Only *CIP6* (since 1992), *Green certificates* (since 1999) and one kind of feed-in tariff (*Conto Energia,* since 2005) have been active during our period of analysis.[1] Quantitative complete information on the national incentive schemes is however not available at the regional scale.[2] We therefore analyze regional policies and regional implementations of national calls. Regional schemes include grants that can cover up to 70-75% of the total cost (excluded VAT) of the new plant, and tax exemptions for expenditures in RES installations (introduced in the 1990s), such as a reduction of VAT by 10% and the possibility to deduct 36%-55% of the cost of the plant from income taxes over ten years. We also included regional subsidies to R&D for RES and feasibility studies of RES capacities.

We test whether the political orientation of local governments plays a role. The hypothesis is that the presence of green parties into local regional government could have positively

[1] CIP 6 is an instrument launched in 1992 with the objective to facilitate the liberalization of the electricity market after three decades of monopoly by the national company ENEL. It has been estimated that in the period 1992-2012 CIP 6 distributed 13 billion Euros in the form of an incentive tariff for green electricity aimed at stimulating the installation of new renewable energy plants. Feed-in tariffs are incentives designed to promote the production of electricity by photovoltaic systems. They guarantee a favourable tariff for each kWh produced by RES installations recognized by the Manager of Energy Services (GSE) and fed into the grid. They include the European programme Conto Energia active since 2005 and a comprehensive fee (*tariffa onnicomprensiva*), in place since December 2007, both targeted to photovoltaic installations smaller than 1 MW. Since 1 January 2009 Net Metering (*scambio sul posto*) applies to power plants up to 200 kW using renewable sources and working in cogeneration. Since 1999 energy producers have been required to generate each year a given minimum share of their electricity with RES or to buy a corresponding amount from another producer. Each MWh produced from renewable sources is granted, each year, a Green Certificate, which can be used to fulfil one's obligation or sold to other producers. In 2005 White certificates were introduced as a way of promoting energy efficiency.

[2] Data are available only on the number of the installations who qualified for support, but not on the incentivized production, and only since 2002.

influenced the development of RES, whereas centre-right coalitions, inclining towards the nuclear alternative, could have acted in the opposite direction.

Research capacities and public-private-academic partnerships are likely to be determinants of RES innovation. We consider both the general public and private expenditure in R&D as a share of GDP and the specific RES research funded by national government in physics and industrial engineering over the observation period.

We control for regional geographic variability. Net energetic import, net energetic balance with other Italian regions (key objective variables in regional energetic plans), and installed productive capacities of wind and photovoltaic power are used as proxies of natural endowments.[3] We also control for the presence of regions whose development is lagging behind (those included in the Objective 1 list of EU regional policies) as this factor may influence their capacity to develop RES research. Different market dynamics and expectations about future local market growth (Johnstone et al. 2010b) is a further local context variable that could contribute to determine regional variability in RES innovation We use the dynamics of electricity consumption as a proxy.

Finally, changes in the average price of oil account for the influence on RES patenting of what happens in the general energy market.

Our measure of local innovative activity is the number of patents produced by local organizations (firms, research centres and universities) during the period 1997-2007. We are aware that using patents as a proxy of innovation has a certain number of pitfalls. They are an incomplete measure of information flows as not all patents are registered (Almeida and Kogut 1999; Autant-Bernard 2001; Alcacer and Gittelman 2006): due to a poor representation of the services sector, registered patents explain at most 30% of innovative activities. Even more importantly, they do not allow us to identify the qualitative differences between innovations that have not been commercialized and those that have offered high economic returns. "Accordingly, the results of studies using patent data are best interpreted as the effect of an 'average' patent, rather than any specific invention" (Popp 2005: 214). Most authors agree that the majority of process innovations tend not to be patented as firms opt for industrial secrecy and try to prevent knowledge spillovers, so that patents contain almost only "end of pipe" solutions. Another potential drawback of patents, specific to environmental studies, is that policy changes may affect the direction of patenting activity. Market-based pollution control policies, for example, tend to induce a shift from cost-reducing to emission-reducing innovation. This may complicate the interpretation of time trends of technological innovation (Popp 2007). Despite these drawbacks, patent applications are among the few measures able to provide a comprehensive picture of innovative activities and that are usually filed early in the research process (Griliches 1990). They are used to measure innovative activities in most previous studies on this issue, including Johnstone et al. (2010b) and Popp et al. (2011) upon whose work this paper is building.

Our explained variable, the number of RES patents, is non-negative, discrete, and often takes a zero value – features well fitted by a Poisson model. Following Cameron and Trivedi (1998), the number of patents n_{it} for observation *i,* at time *t* follows the probability distribution

$$\Pr\{n_{it}\} = e^{-\lambda_{it}} \frac{(\lambda_{it})^{n_{it}}}{n_{it}!}$$

The parameter λ_{it}, is linked to the explanatory variables in a log-linear form:

[3] The installed capacity of hydroelectric power is correlated with regions' net energetic balance.

$$\ln \lambda_{it} = \beta' X_{it} + \mu_{it} + \varepsilon_{it} \qquad (1)$$

where i takes values from 1 to 20 (Italian regions), t ranges from 1997 to 2007, λ_{it} is number of RES patents in region i in year t, X_{it} is the vector of regressors listed in Table 1, ε_{it} is within-entity error, and μ_{it} is between-entity error, measuring the difference between the average patents of region i and the average patents in the entire country. We use a lag structure to take into account the delay between the moment general public and private research takes place and its impact on innovation. Due to the lack of suitable data we could not do the same for specific research on RES. A time lag is introduced in the model also for public policies and for political orientation of regional governments.

3. Data

We use NUTS-2 regions[4] as basic territorial unit for analysing RES innovation patterns. The Italian Regions represent an actual level of governance since they play a direct role in the implementation of energy policy with respect to GHG emission reduction targets and to safety provision. Most regions also establish the implementation framework of new renewable plants, by issuing regulatory acts that set the level of luminosity and noise allowed for new RES plants, as well as the locations that are forbidden for settlement of RES plants (for example by establishing minimum distances from the coast for off-shore wind turbines). Regional energy policies play a role of innovation inducement, either directly by subsidizing research in RES, or indirectly by subsidizing the production of RES. Data on public incentives have been obtained from ENEA (Italian National Agency for New Technologies): 5212 laws were reviewed for all 20 regions. We recovered regional regulations regarding subsidies to R&D for RES, energy efficiency, grants for capital costs (including tax deductions) and feasibility studies of RES capacities. Data on the average oil price (International Energy Agency, IEA) were used to investigate the inducement effect generated by the change in the factors of production's relative prices.

We construct a database of environmental patents using the classification by Johnstone et al. (2010b). The strategy is in two steps. First, we recovered patent applications from the Italian Patent and Trademark Office (UIBM). The use of the UIBM database provides a good picture of regional and provincial patenting behaviour and allows us to identify the innovations that emerged as an adaptation of foreign technology to local domestic conditions. In addition, it includes patent applications by small firms that likely could not afford the additional costs required by applications to the European Patent Office (EPO).[6] Using the mentioned classification we identified 4756 patents subdivided in 5 categories (wind, solar, ocean, geo-thermal and biomass).[7] The main inconvenience of the UIBM database is that, unlike the EPO database, the relevant subclasses are not developed to their finest level. As a result, we had irrelevant patents included into our set. Thus, in a second

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[4] The Nomenclature of Territorial Units for Statistics (NUTS) is a geocode standard, developed and regulated by the European Union, for referencing the subdivisions of countries for statistical purposes. The current NUTS classification lists 97 regions at NUTS-1, 271 regions at NUTS-2 and 1303 regions at NUTS-3 level.

[5] http://enerweb.casaccia.enea.it/enearegioni/UserFiles/osservatorio.htm

[6] Patents registered in the UIBM also include applications by multinational and foreign inventors who intend to commercialize their innovation in Italy. The share of foreign applications over the total in our time span is however pretty low (in the case of solar technology, for instance, below 10%) and some of them could have been the result of innovation activities taking place in the Italian branches of multinational enterprises. For these reasons we have retained the whole dataset of UIBM patents.

[7] Patent data refer to both photovoltaic and thermal solar technologies, whereas data on solar installed capacities refer only to photovoltaic.

step, we checked each patent individually and retained only those actually referring to RES production, ending up with 1940 relevant RES patents.

In examining spatial patterns of RES patents one should account for the large differences in size between Italian regions. In order to do so we use the local pool of researchers working within public and private institutions. This also controls for the omitted variables bias that typically affects cross sectional regressions of innovative output on research inputs (Bottazzi and Peri 2003).[8] We use a measure of the growth of local markets (the increase in electricity consumption) as a control variable to investigate the degree to which dynamic markets are determining the intensity of innovation activities. The source of data on regional electricity consumption and on installed capacities of hydroelectric, wind and photovoltaic power is TERNA (Italian Electricity Transmission Grid Operator).

Data on R&D are constructed using two sources. One is ISTAT (Italian National Institute of Statistics) from which we recover data on the local pool of researchers and data on public and private expenditure for research. The other is MIUR (Ministry of Education University and Research) from which we recover data on all the public research projects on topics related to renewable energies which received funding during our period of analysis. In order to collect data on projects pertaining RES we performed a keyword search, resulting in 1693 projects.[9] The search result was refined through a reading of titles and abstracts of each project, after which only 151 relevant research projects were retained within our dataset. Between 1997 and 2007 the total funding granted to RES related research projects by MIUR resulted to be €22,810,000.

Data pertaining to social acceptance of and political support for the development of RES were recovered from different sources. Data on the presence of green parties and the colour of political coalitions in regional governments in the last three elections (1995, 2000 and 2005) were recovered from major national newspapers websites or directly from the regions official websites. The data on installed capacities were recovered from TERNA. The source of data on financial schemes is ENEA.[10]

4. Descriptive analysis

One notable feature emerging from a descriptive analysis is the delay of innovation activities in the field of renewable energies registered in Italy with respect to those registered in the European Patent Office (Figure 1 and 2). In Italy patenting for all RES is very low until the mid 1990s, whereas the EPO had been registering a remarkable activity already in the 1980s. The further increases in RES innovation rates registered at the European level in the last part of the observation period concur with the liberalization of the energy sector (1998), the widespread introduction of RES incentive policies in the EU and OECD countries at large from the early 1990s, and the ratification of Kyoto Protocol (2001) that prepared the ground for the introduction of the EU emission trading scheme in 2005. With a few notable exceptions (such as the publicly funded construction of the

[8] An increase in resources devoted to R&D fosters innovation, but at the same time an increase in innovative output increases the productivity and the profitability of further research and induces higher research expenditure and innovation.
[9] Keywords used include biomass, renewable, waste, biogas, geothermal, solar, solar energy, hydroelectric energy, thermal, geo-thermal, ocean, wind, wind energy.
[10] Osservatorio Politiche Energetico-Ambientali Regionali e Locali, http://enerweb.casaccia.enea.it/enearegioni/UserFiles/osservatorio.htm

largest photovoltaic plant in Europe near Salerno, completed in 1993), incentive policies for RES remain limited, in Italy, until the late 1990s.[11]

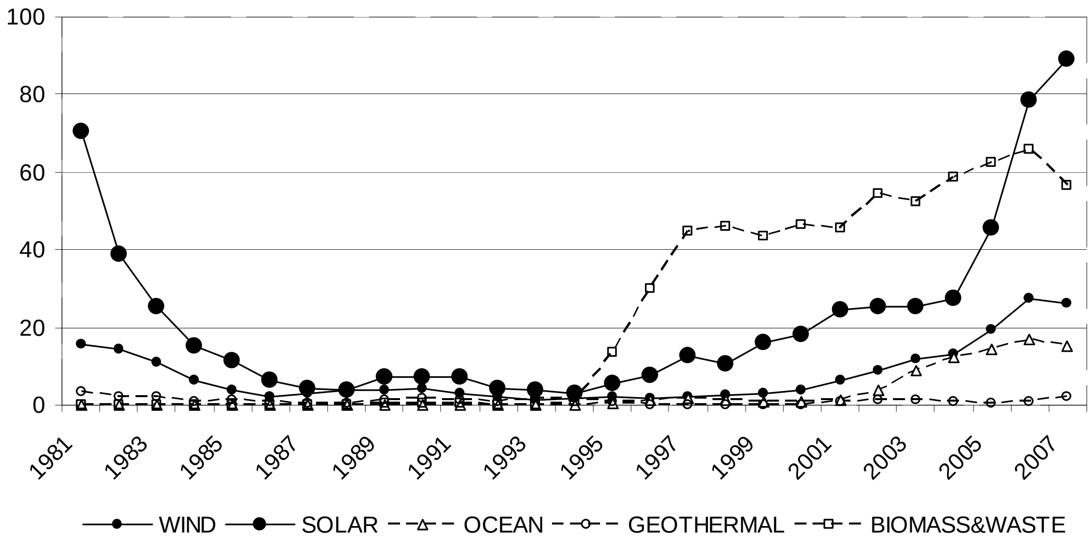

Figure 1. UIBM Patent applications for RES (own elaboration)

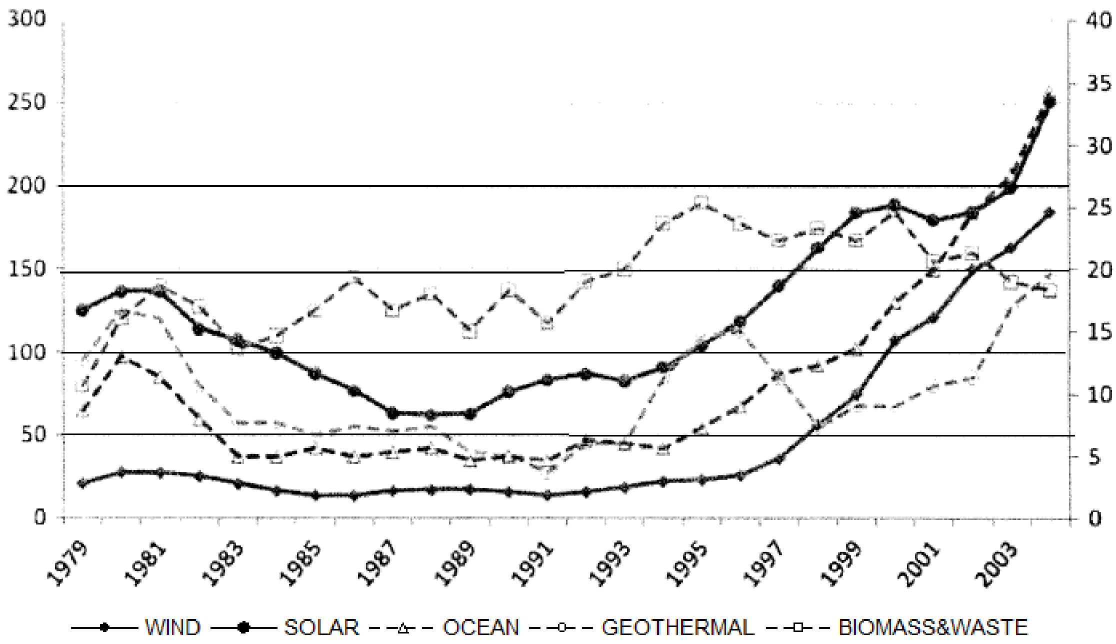

Figure 2. EPO Patent applications for RES by type of renewable technology (3 year-moving average) Source: Johnstone et al. (2010b)

Although rates of RES innovation in general start rising in Italy in the mid 1990s, the trends followed by innovation in different renewable sources do not overlie. UIBM wind power patent applications exhibit a pattern similar to those presented to the European Office, although on a lower level, with an increasing trend starting in the late 1990s-early

[11] Also the United States, who had been until 1980 in a leading position in financing expenditures for photovoltaic devices, experienced a sharp decline in RES incentive policies during the Reagan administration caused by a lower priority given to the federal strategy for alternative energy research (Braun et al. 2010).

2000s. The technologies for the production of energy from biomass experienced a spectacular patenting activity in the decade between 1995 and 2005, more important than those in the solar sector. They then register a decline starting from 2005, partly due to the increase in public incentives to other types of renewable energy and to solar in particular. Solar (thermal) technologies take off in Italy after 2005, supported by significant incentive packages (Braun et al. 2010).

4.1 Natural endowments

Natural endowments, in terms of relative abundance of renewable energy sources, contribute to determine a large regional variability in RES production. Wind power installations, in particular, strongly concentrate in the few Southern regions with suitable natural conditions. Southern region Apulia, that does not have hydro or thermo power potential, was among the first regions to implement national calls for RES incentives and finance wind and solar installations. Despite the incentive mechanisms, Alpine regions such as Aosta Valley, a big producer and exporter of hydroelectric power, have got negligible levels of solar and wind installed capacities.

Natural endowments do not however turn out to be significant determinant of RES innovation patterns. Our empirical evidence on Italy shows a clear decoupling, at the local level, of RES production and innovation. In 2007, at end of our observation period, the Northern regions of Lombardy, Piedmont, Aosta Valley, Liguria, Trentino Alto Adige, Veneto and Emilia Romagna together hosted about 1.6% of the total installed MW in wind and photovoltaic, but had originated 66.3% of patents pertaining those technologies. Objective 1 regions alone (Campania, Apulia, Basilicata, Calabria, Sicily and Sardinia) had 41.2% of installed capacities and 7% of patents. The gap is widening over our time span: aggregate RES installed capacities are increasing faster in the South, whereas the share of innovation activity is increasing in the North (from 40% in 1997 to 67% in 2007) and decreasing in the South (from 10% to 7% over the same decade).

The available data do not separate wind and photovoltaic installed capacities during our observation period. This does not appreciably bias our results, however, because both wind and solar installed capacities in Northern regions remain close to zero until 2006. Photovoltaic installed capacities in Northern regions increase drastically only after 2008 (following the introduction of *Conto Energia* subsidies), leading to a quite uniform distribution of production across Italy. This reflects a distribution of natural endowments less polarized for solar than for wind conditions, which however does not suffice, without incentives, to stimulate the diffusion of photovoltaic installations.

4.2 Financial incentives

One hypothetic explanation of such production-innovation decoupling are the faster rates of increase of electricity consumption in Northern Italy and the consequent expectations of higher economic returns from innovation. Another potential justification could derive from the regional variability in subsidies to RES technologies. National policy schemes are usually translated into regional calls with different implementation procedures and timings. The adoption and implementation of Regional Energy Action Plans (REAP) has worked with high variability among regions, with a clear North-South divide. Rather quick in elaborating and implementing their REAP have been Trentino Alto Adige (Bolzano Province 1997), Lazio (2001), Tuscany (2001), whereas the last have been Southern regions such as Sicily (2009), Campania (2009) and Basilicata (2010). In addition, regional calls make available to applicants national funds (equally accessible to all regions), supplemented however by regional funds and, in some Southern regions, European structural and cohesion funds. Figure 3 shows, as an example, the heterogeneity among Italian regions in the implementation of Solar roof programs.

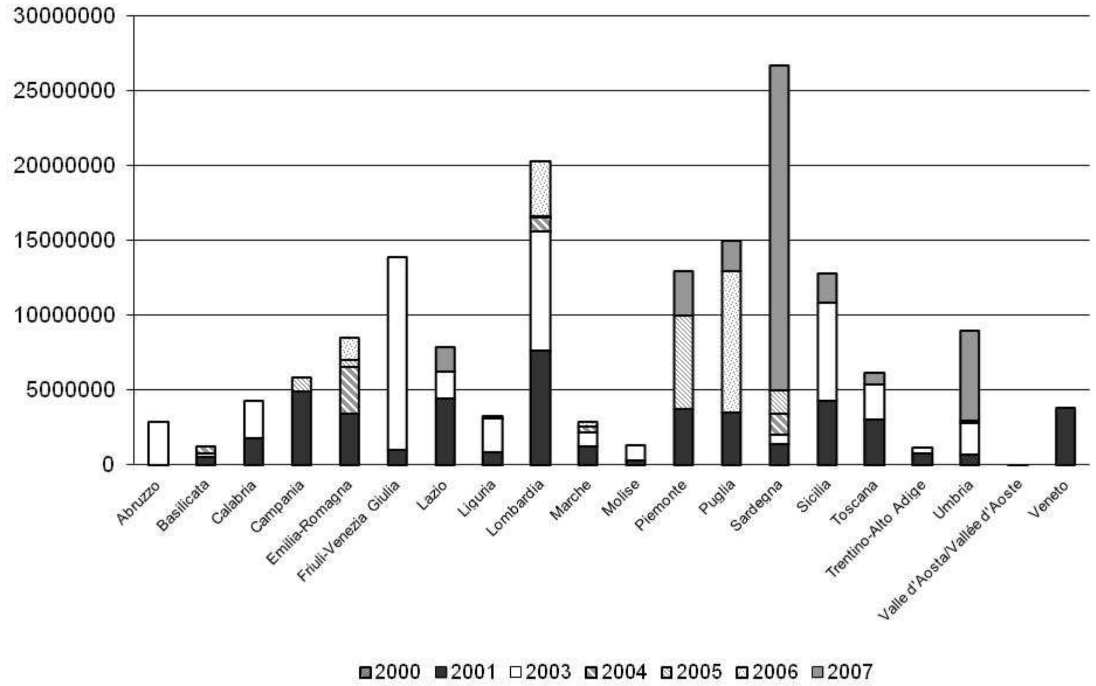

Figure 3 Public grants (€) on capital costs for solar technology by region

All financial incentives included in our analysis refer to RES production, but, by forcing energy producers to obtain a given share of their production from renewable sources, they could contribute to create a critical mass of demand for green energy technology which in turn could motivate larger producers, and enable smaller ones, to invest in R&D. For example ENEL, former monopolist in the Italian energy market, that since 2008 has had to become active also in the sector of renewable sources, has made significant investments in R&D that led to the development of the world's first hybrid solar-geothermal power plant.

4.2 Regional governments

Greener regional governments can be thought of as the reflection of local environmental concerns and hence, to a reasonable extent, of the level of community consensus around the development of renewable energies. In our period of analysis we capture the effect of three regional elections (1995, 2000, 2005; Table 2). Five regions show a stable presence of green parties in regional councils: Basilicata, Umbria, Emilia Romagna, Marche and Tuscany. Lazio, Abruzzi and Liguria see the presence of green parties in local governments at the beginning and at the end of our period of analysis. In Piedmont and Sardinia green parties are present in regional councils only after the 2005 elections. The correlation coefficient between the presence of green parties and the amount of public incentives to RES is 0.11. Green parties are small, and are present in regional governments only when they succeed to tie coalitions with other political forces. At the beginning of our observation period the national government, headed by a centre-left coalition, effectively implements the European law for market liberalization of the energy sector and enhances national incentives programmes to renewable energy sources. The presence in local governments of centre-left-green coalitions may have increased the chances of successful implementation of policies in support of RES. Coalitions of centre-left and green parties in local governments and the amount of public incentives to RES present a correlation coefficient of 0.14.

Table 2 Presence of green parties in regional governments

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Piedmont											
Aosta Valley											
Lombardy											
Trentino-Alto Adige											
Veneto											
Friuli-Venezia Giulia											
Liguria											
Emilia-Romagna											
Tuscany											
Umbria											
Marche											
Lazio											
Abruzzo											
Molise											
Campania											
Apulia											
Basilicata											
Calabria											
Sicily											
Sardinia											

In the 2000 elections the centre-right coalition (Forward Italy, National Alliance and Northern League) won in 8 out of 15 regions (the most populous ones, except Campania). Forward Italy's members were elected President of Region in Piedmont, Lombardy, Veneto, Liguria, Apulia and Calabria. It was a highly heterogeneous coalition: Forward Italy (Forza Italia) had liberal-conservative and Christian democratic components. The National Alliance supported traditional values and presidentialism. The Northern League had a federalist and regionalist program. Little support was mobilised under their governments for the implementation of renewable energies at the local level. In fact these regional elections marked profound changes in the political landscape and diverted attention away from energy policies. During our period of analysis the correlation between the presence of centre-right coalitions in regional government and the amount of public incentives for RES is -0.09. The support for nuclear power by the centre-right political forces became explicit after the 2008 national elections. The central government nuclear agenda faced strong local opposition and ten Italian regions (Basilicata, Calabria, Emilia-Romagna, Lazio, Liguria, Marche, Molise, Apulia, Tuscany and Umbria) succeeded to block a law aimed at reopening nuclear facilities (closed after a referendum in 1987).

4.3. Local research capacities

One of our principal hypotheses was that local skills and research matter for RES activities. Examining our database, RES innovation appears to concentrate in large research centres or in areas where they benefit from exchange of knowledge. RES patents for different technologies turn out to be highly correlated: the correlation between the number of solar patents and the number of wind patents by region is 0.61; the correlation between the number of solar patents and the number of biomass patents is 0.59; the correlation between total RES patents and solar patents is 0,86. There does not appear to be local specialization of RES research: where RES innovation activities take place, they tend to interest all main RES technologies (solar, wind and biomass). Local concentration of innovation is confirmed by a principal component analysis regrouping patents in solar and wind technologies. The share of the variance explained by the first principal components is quite high: 70% of the variance is explained by global RES patenting activities.[12]

Total patents turn out to be highly correlated with the local intensity of general research and development activities (0.55), correlation coefficients being higher for solar (0.32) and wind (0,34) and biomass(0,42), and low only for geothermal (0,09). Public investments in specific research on renewable energies also play an important role. The correlation coefficient between public research grants in the field of renewable energies and RES patenting is 0.31. Again wind and solar patents are more sensitive to R&D funding, correlation coefficients varying between 0.39 (wind), 0.31(solar), and 0.17 (biomass).

Research projects financed by MIUR are assigned to one main research centre, but they are generally the fruit of collaborations among several universities. We note that over the years the average size of financed research networks decreases from 7 to 4 universities. This might be due to a process of specialization, with research centres progressively focusing on specific research topics. Through a principal component analysis of the research themes of funded projects we test the local specialization of research, trying to see whether one or more scientific disciplines play a determinant role. The share of the variance explained by the first 3 principal components is quite low. There is very low correlation across scientific fields, the highest correlation coefficient being between physics and industrial engineering (0.13). The main disciplines to which funded projects belong are Computer science and Industrial Engineering (54%), Chemistry (15%), Agronomy (12%), Architecture and Civil Engineering (11%), Physics (6%), Earth Sciences (2%), Biology (1%).

A correlation analysis confirms the role of specific research: correlation coefficients between the number of MIUR projects financed for physics and total RES patents is 0.20. The correlation coefficients are higher for wind patents (0.34) and for solar patents (0.34) and lower for biomass(0.05).

The contribution of industrial engineering is decreasing over time, while is increasing that of chemistry (Figure 4). This is at least partly explained by the evolution of the solar technology, increasingly requiring knowledge on semiconducting materials (silicon-based or organic materials). Chemists and materials scientists collaborate with physicists and engineers in developing innovations such as thin-film photovoltaic solar panels (Hamilton 2011). The evolution of solar and wind technology is also determining the increased participation of architecture and civil engineering in research concerning the integration of RES installations in urban and natural landscapes.

[12] PCA tables are available on request.

4.5. Market conditions and energy prices

According to induced innovation theory, changes in factor prices appear to induce innovation as firms look for solutions to minimize their costs (Hicks, 1932). There is however little direct evidence in the empirical literature that technological change induced by the increase in oil prices in the 1970s explains the variation in total energy demand: in the presence of aggregate shocks such as oil price increases we do not distinguish substitution along the energy demand curve from a shift of the curve due to technological change. The link between factor prices, technology and factor demand is quantified by Linn (2008) who, by including factor demand in the analysis, is able to state that a 10 percent increase in the price of energy leads to technology adoption that causes a one percent decrease in energy demand. The element of novelty in Linn's analysis stems from comparing existing manufacturing plants, that are bound to their technology, and entrants, that can adopt the same technology and be equally energy intensive or adopt less energy intensive technology than existing plants. When the price of energy increases the incumbent plants would move along their demand curve whereas the entrants' demand curve would shift inward. Variations in energy prices do not only generate adoption of specific types of energy-saving technologies (Jaffe and Stavins 1995, Newell, Jaffe and Stavins 1999) but also intensify innovation activities. In the USA, Popp (2002) finds that between 1970 and 1994 patenting activity for different energetic fields responds quickly to increases in oil prices but decreases before the energy prices fall. He attributes this effect to decreasing returns to R&D. Taylor (2008) finds a positive relationship between energy prices and innovation in the non-hydro renewable technologies. Decomposing the aggregate energy price, he finds a strong positive and significant contribution of the variation in petroleum prices to non-hydro RES patents. Finally, he predicts that an increase of 10 RES patents per year "would require either a $19.3 million dollar increase of US government spending or an increase in average aggregate energy prices of $0.38 per million BTU (in $1999)" (Taylor 2008:24).

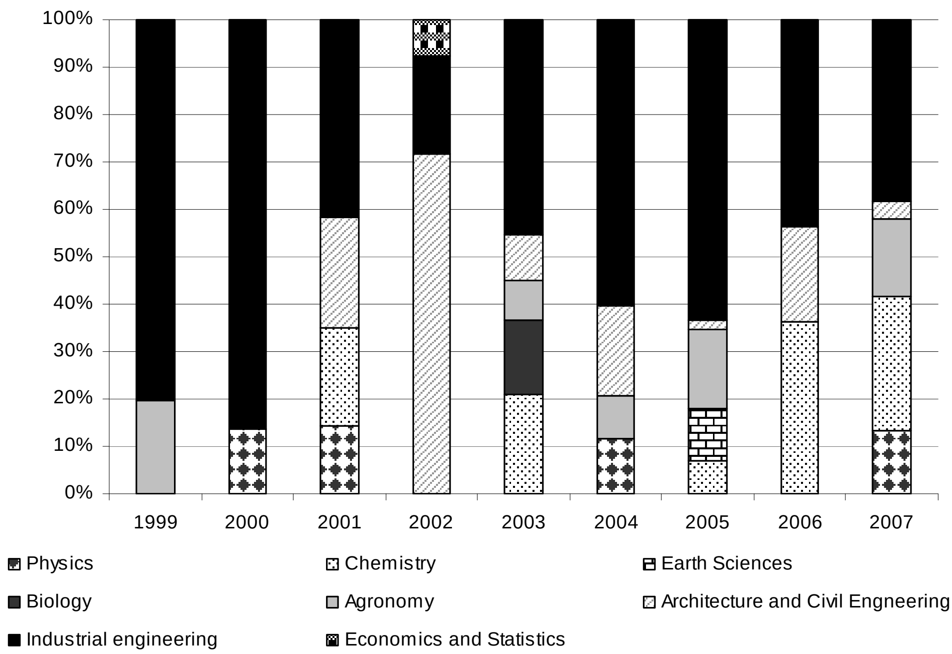

Figure 4 Distribution of public R&D projects financed by scientific field

In Italy, we can observe a positive association of patenting activity and oil price increases (Figure 5). In particular for the solar and wind technologies the year 2005 represents a breakpoint. While being relatively stable during the 1990s, the price of oil increases after 2005 due to hurricanes in the Gulf of Mexico and United States refinery problems associated with the introduction of ethanol as a gasoline additive. The variations in oil prices have a strong impact in Italy, due to its high dependence on energy imports. Natural gas gradually displaces oil, becoming the most important fuel for electricity generation in Italy after 2004 (EWEA 2012).

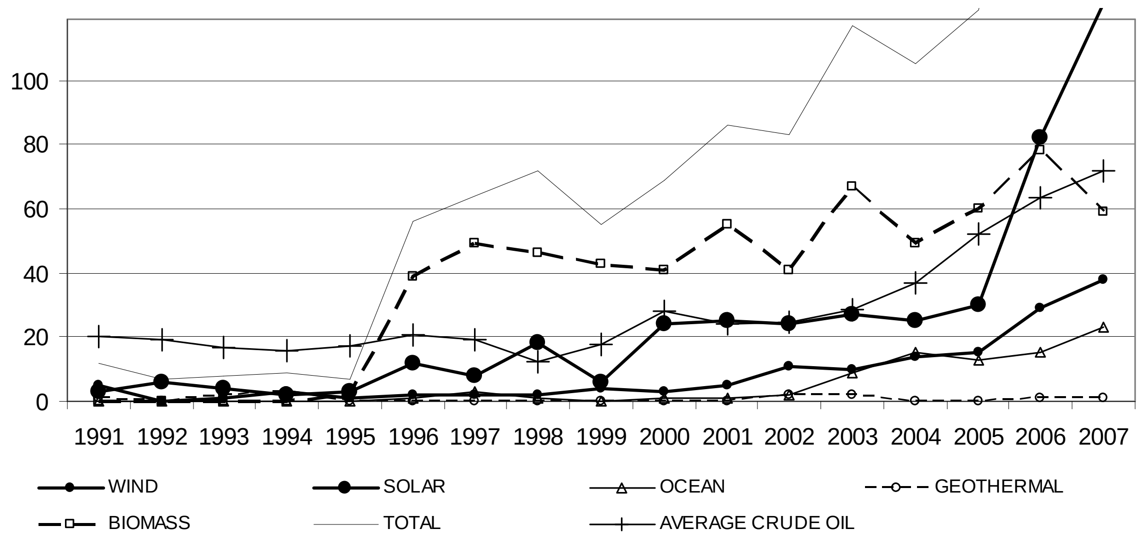

Figure 5 Evolution of RES patent applications in Italy versus average price of crude oil (UIBM patents)

The number of RES patents applications patents and the average price of crude oil appear correlated (0.30), however this may be the result of correlated movements of energy prices and RES subsidies.

5. Estimation results

We have estimated the following model:

$$\ln \lambda_{it} = \beta_1 General\_RD_{it-2} + \beta_2 Specific\_RD_{it} + \beta_3 RES\_incentives_{it-1} + \beta_4 Political\_color_{it-1}$$
$$+ \beta_5 Growth\_Installed\_PV\_capacities_{it} + \beta_6 Growth\_Installed\_Hydro\_capacities_{it}$$
$$+ \beta_7 Share\_Installed\_PV\_capacities_{it} + \beta_8 Net\_energy\_imports_{it}$$
$$+ \beta_9 Growth\_elec\_cons_{it} + \beta_{10} Objective1_{it} + \beta_{11} Growth\_oil\_price_{it} + \mu_{it} + \varepsilon_{it}$$

We run fixed effect and random effect estimations for RES patenting. A fixed effects approach would have controlled for the average differences across the twenty regions such as unobserved fundamental disparities in renewable energy innovation patterns (as done in the case of wind by Soderhölm and Klaassen 2007). A Hausman test, however, suggests retaining a random effects rather than a fixed effects model. We test the null hypothesis that the differences in coefficients are not systematic. A chi-square test cannot reject the null hypothesis with a significance of 10%. Therefore the individual effects are supposed to be random. Regional differences such as institutional variations are not fixed over time. For all models we test whether all coefficients in the model are different from zero. The F test indicates that we can reject the null hypothesis at a 1% significance level. We have retained only the most significant model, the one considering solar, wind and biomass patents. Estimation results are presented in Table 3.

Natural endowments. Evidence from the descriptive analysis is confirmed by the estimation results: natural endowments in wind, solar and biomass sources, proxied by installed capacities, do not play a significant role in explaining regional RES innovation patterns.
A significant role is played instead by the overall energetic endowment: a 1 TWh increase in a region's net energetic imports is associated with an 8.4% increase in the total number of RES patents, with a 10.5% increase in solar patents, and with a 6.6 and 6.5% increase respectively in wind and biomass patents. A region's net energetic balance with other Italian regions acts, with less weight, in the same direction. A 1 TWh increase in inter-regional imports leads to a 2% increase in the mean of RES patents. An energy market in deficit is associated with a higher propensity to patent in renewables.

Financial incentives. An increase in local subsidies has a positive impact on RES patenting activity. A one million euro increase in financial incentives augments by 1.9% the mean number of overall RES patents, and by 3.8% and 2.8% the mean of solar and wind patents respectively. The impact of financial incentives is not statistically significant for biomass technologies.

Regional governments. The presence of green parties within centre-left coalitions at the head of regional councils positively and significantly affects patenting in solar technologies. Holding all other factors constant, regions governed by coalitions of centre-left and green parties see an increase in patenting of 31% in overall RES patents, 42% for solar energy and 86% for wind energy. Again the coefficient is not statistically significant for biomass technologies. Centre-left and centre-right coalitions cannot be simultaneously included in the model because of collinearity. We have retained centre-left. In the alternative version (Appendix 3) the estimated incidence rate ratio for the presence of centre-right parties in regional governments is 0.70, implying an average 30% reduction in the number of all RES patents for given covariate values and a decrease of 43% for solar patenting.

Local research capacities. The estimated coefficient of public and private expenditures for research is positively and significantly contributing to RES patenting: the higher the general R&D expenditure, the higher the innovation activity in RES technologies. Our finding is consistent with Haščič et al. (2010) who maintained that an important determinant of environmental innovation is the general innovative capacity. Coefficients of public and private regional expenditure in R&D are higher for solar and wind patents than for biomass: a 1% increase in R&D research expenditure increases by 16% the mean number of solar patents, by 22% the mean number of wind patents, and by 20% that of biomass patents.

Renewable-specific research funding to universities turns out, however, to be the strongest determinant of the emergence of RES innovation. A slope-dummy variable for RES research projects funded by the central government in different scientific fields allows us to also test whether an increase in national research funding in different disciplines has a different impact on RES patents. We find that the presence of funding for RES research projects in physics increases by 27% the average number of RES patents, while it doubles the mean of solar patents. Our results confirm those by Cainelli et al. (2011) who identify cooperation between innovating firms and local universities as the main driver of environmental innovation. This impact is statistically significant at the 1% level. A one million increase of funding for RES research projects doubles the mean of solar patents and triples the mean of wind patents. The impact of renewable-specific R&D investments on innovation in biomass energy does not result to be statistically significant.

Table 3 Determinants of renewable energy patenting in Italy. Random effects Poisson model, incidence rate ratios

	All RES patents	Solar power patents	Wind power patents	Biomass power patents
Loglikelihood	-503.09	-357.47	-182.63	-352.52
General public and private regional R&D expenditure (rate over GDP, t-2)	1.237 [0.0450]***	1.161 [0.0591]***	1.223 [0.1041]**	1.197 [0.0559]***
RES research funded by national government (total MIUR projects, million €)	1.205 [0.2414]ns	2.176 [0.7826]**	3.090 [1.997]*	0.920 [0.2857]ns
RES research funded by national government in physics(dummy)	1.277 [0.1882]*	1.823 [0.4199]***	0.954 [0.4632]ns	1.076 [0.2580]ns
RES public incentives from regional governments (million €, t-1)	1.019 [0.0054]***	1.038 [0.0094]***	1.028 [0.0160]*	1.0014 [0.0086]ns
Regional government political colour (centre-left and greens, t-1)	1.311 [0.1436]**	1.423 [0.2796]*	1.859 [0.5731]*	0.925 [0.1563]ns
Growth of regional capacities of photovoltaic and wind power (MW)	1.004 [0.0011]***	1.004 [0.0022]ns	1.007 [0.0032]**	0.9985 [0.0026]ns
Growth of regional capacities of hydroelectric power (MW)	1.00021 [0.0009]ns	0.999 [0.0018]ns	0.999 [0.0030]ns	1.00018 [0.0014]ns
Share of regional photovoltaic and wind power installed capacity (MW)	0.990 [0.0091]ns	1.000 [0.0179]ns	1.005 [0.0284]ns	0.982 [0.0134]ns
Net energetic balance with other Italian regions	1.016 [0.0058]***	1.013 [0.0104]ns	1.013 [0.018]ns	1.019 [0.0083]***
Net energetic import (TWh)	1.084 [0.0188]***	1.1050 [0.0314]***	1.066 [0.040]*	1.0654 [0.0250]***
Growth of regional electricity consumption	0.997 [0.0017]ns	0.998 [0.0034]ns	0.997 [0.0061]ns	0.999 [0.0024]ns
Objective 1 status	1.406 [0.880]ns	0.559 [0.3775]ns	0.439 [0.3983]ns	1.5830 [1.1480]ns
Growth of average oil price	0.998 [0.0012]ns	0.998 [0.0023]ns	1.003 [0.0041]ns	0.998 [0.0017]ns
Sigma_u (standard deviation of random intercept)	1.067	0.845	1.046	1.194

N.B. Standard errors are displayed within brackets. ***, **, *, n.s. denote significance levels of 1%, 5%, 10% or else not significant; the constant was not significant and was dropped from the estimations.

Objective 1 status. We expected to capture part of the regional differences in RES patenting through a dichotomic variable indicating the level of economic development and the presence of European support policies. Regions such as Sicily, Sardinia, Basilicata, Calabria, Campania and Apulia are labelled as EU Objective 1 regions, being characterized by the fact that the mean income is less than 75% of the European average. They benefit from national and European funding seeking convergence and cohesion among member states. Some of the support also targets RES adoption. In our analysis, however, being an

Objective 1 region does not appear to be associated with the pattern of RES patenting activity.

Finally, the growth of installed capacities of photovoltaic and wind power has a positive impact on RES patent filings: the incidence rate for all RES patents and for solar technology is 1.004: a 1% increase in the rate of growth of installed capacity of wind power is associated with an increase by 0.4% in the number of wind patents. The rate of growth of the hydroelectric power installed capacity is not significantly associated with solar and wind patenting.

Market conditions and energy prices do not appear to influence RES patenting behaviour. The coefficient for the average price of oil is not significant for total RES patents and by technology type. This result is consistent with those by Johnstone et al. (2010b). They find that environmental public policies, rather than prices, are the main driver of innovation in renewable energy technologies. We also do not find a significant contribution of the growth of electricity consumption to the emergence of RES innovation.

6. Conclusions

The objective of this paper is to identify the extent to which the evolution of renewable energy patenting is determined by public intervention and local context. A panel analysis of Italian regions over the decade 1997-2007 investigates the role of natural endowments, policy instruments such as financial incentives and public R&D expenditures, political support, market conditions and oil prices as potential determinants of spatial heterogeneity in RES innovation. The number of patent applications in the field of renewable energy technology is used as proxy of innovation, within a random effect model that allows us to take into account geographic differences such as wind/solar conditions (natural endowments) and institutional differences that are not fixed over time.

As expected, a clearcut contribution to RES innovation activities comes from R&D: the level of general research expenditure, and still more renewables-specific research funding to universities emerge as the prime determinants in the observed spatial heterogeneity in innovation patterns. RES innovation activities benefit from networks facilitating the exchange of information, and academic research appears to be a critical driver of technological change. Tighter synergies between authorities in charge of energy policies, universities and industries could foster market acceptance of renewables and thus be an effective element of the innovation inducing mechanism. If the positive sign of socio-political endorsement in our analysis is in line with previous studies and does not surprise, the relative impacts of different policy instruments on innovation convey useful signals for policy makers and deserve further inquiry in an international context.

A descriptive analysis shows a clear decoupling of production and innovation activities: renewable energy production is concentrated in Southern Italy, and particularly in Objective 1 regions where European structural and cohesion funds have been devoted to the installation of RES technologies, whereas patenting activities are highly concentrated in the North. Among the hypothetical explanations, our empirical results reject the expectation of higher economic returns from innovation in the regions with more favourable prospects of market expansion. We find, instead, evidence of induced innovation: financial incentives to renewable energies are associated with higher numbers of RES patent filings. Interestingly, European structural and cohesion funds devoted to Objective 1 regions have impacted on the adoption of RES technology but not on innovative activities.

As experienced also in other countries, national, top-down objectives did not always find easily their way into locally accepted policies.[13] In the face of national incentives and R&D policies equally accessible to all regions, significant local variability has been partially due to an insufficient mobilization of local planning authorities. The latter's attitude towards environmental issues and, in the case of Italy, towards the nuclear alternative appears to have had an impact: the estimation results show that pro-nuclear local governments succeeded in diverting attention away from RES activities, and that greener local governments have been able both to hold back repeated attempts by national policy makers to reintroduce nuclear power (until a second referendum in 2011 confirmed the 1987 result and marked the end of the debate) and to foster RES technological change.

Social acceptance is clearly an influential factor in the development and diffusion of RES technologies. Our regional analysis allows us to highlight the role played by local communities and stakeholders in the marked local diversity of RES innovation rates in the Italian sub-national landscape. Awareness of the importance of such bottom-up inputs may enable policymakers at different levels of government, for example, to refine the design of policies and constraints in such a way as to more effectively pursue the desired level of green technology adoption and innovation.

The present analysis could be refined in the presence of suitable data on recent national policies (such as feed-in tariffs) and on regional variability (for example using physical data on RES natural conditions). The investigation could also be extended to consider the role of international and domestic knowledge spillovers for the agglomeration of RES at a regional level.

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[13] In the Netherlands, the government unsuccessfully attempted to break down the national target of 1000 MW wind energy production to the regional level (Bergek et Jacobsson 2003). A different approach was adopted in the United Kingdom, where the national government set national targets for renewable energy production and then asked local authorities to set regional targets (Simpson 2004).

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Appendix 1 RES patents according to the UIBM classification and refined by title

Code	Description	RES patents
B09B	*Solid waste disposal*	441
C10L	*Fuels not provided for elsewhere, natural gas, synthetic natural gas obtained by processes not provided for in subclasses C10G, C10K, liquefied petroleum gas, addition of a fuel or the fire to reduce smoke or undesirable deposits or to facilitate the fall soot, fire-lighters*	136
E02B	*hydraulics*	10
F01K	*Functional complexes of steam, steam accumulators, complex functional motorized machines not provided for elsewhere, driving a fluid energy machine cycles or special work*	9
F02B	*Internal combustion piston engines; combustion engines in general*	49
F02G	*Functional complexes of gas engines or hot combustion products; utilization of waste heat of combustion engines, not provided for elsewhere;*	16
F03B	*Machines or motorized machines for liquids;*	96
F23G	*Crematoria, incineration of waste;*	49
H01L	*Semiconductor elements; electric solid state devices not provided for elsewhere*	164
H02N	*Electric machines not provided for elsewhere;*	19
E04D	*Roofing; skylights, gutters; tools for the construction of roofs;*	17
F03D	*Wind motors*	237
F03G	*Motor mechanisms in springs, weights, inertia, or similar, devices or systems producing a mechanical power, not provided for elsewhere or employing an energy source that is not provided for elsewhere;*	118
F24J	*Production or utilization of heat, not provided for elsewhere;*	576
F25B	*Machines, installations and refrigeration systems, systems combining heating and refrigeration systems and heat pumps;*	3

Appendix 2 Descriptive statistics

	Obs	Mean	Std. Dev.	Min	Max
All RES patents	220	5.80	9.04	0	69
Solar power patents	220	1.78	3.81	0	31
Wind power patents	220	0.60	1.32	0	7
Biomass power patents	220	2.67	4.36	0	25
Public and private regional expenditure for R&D (rate to GDP)	220	8.88	4.17	1	20
Chemistry- Environmental MIUR projects	220	0.05	0.22	0	1
Industrial engineering - Environmental MIUR projects	220	0.17	0.37	0	1
Growth of average oil price	220	16	25.86	-34	60
Regional growth of electricity consumption	220	3.15	18.42	-100	110
Growth of regional photovoltaic and wind power(MW)	220	12.14	34.56	-22	277
Growth of regional hydroelectric power(MW)	220	6.05	24.42	-34	265
Regions Objective 1	220	0.3	0.45	0	1
Regional incentives for renewable energy (million €)	220	1.98	5.06	0	31.5
Political colour-Centre-Right orientation	220	0.41	0.49	0	1
Political colour-Left and Greens coalitions	220	0.44	0.49	0	
Net energetic imports (TWh)	220	2.30	5.55	-.95	25.29
Net energetic balance with other Italian regions (TWh)	220	0.67	6.02	-16.53	14.95

Appendix 3 Table 3(b) Determinants of renewable energy patenting in Italy. Random effects Poisson model, incidence rate ratios/Centre-right coalitions

	All types of patents	Solar power patents	Wind power patents	Biomass power patents
Loglikelihood	-500.97	-354.88	-183.65	-352.62
General public and private regional expenditure for R&D (rate over GDP, t-2)	1.229	1.161	1.220	1.199
	[0.044]***	[0.0601]***	[0.0970]***	[0.0560]***
Total MIUR projects: RES research funded by national government(million €)	1.242	2.271	3.491	0.901
	[0.2531]ns	[0.8371]**	[2.3142]*	[0.2767]ns
RES research funded by national government in physics(dummy)	1.303	1.871	0.918	1.100
	[0.1932]*	[0.4330]***	[0.4505]ns	[0.261]ns
Growth of average oil price	0.999	0.998	1.003	0.998
	[0.0012]ns	[0.0023]ns	[0.0041]ns	[0.0017]ns
Growth of regional electricity consumption	0.997	0.998	0.997	0.999
	[0.0017]ns	[0.0033]ns	[0.0060]ns	[0.0024]ns
Growth of regional capacities of photovoltaic and wind power (MW)	1.004	1.003	1.008	0.998
	[0.0011]***	[0.0022]ns	[0.0032]**	[0.0025]ns
Growth of regional capacities of hydroelectric power (MW)	1.0003	0.999	0.999	1.0002
	[0.0009]ns	[0.0018]ns	[0.0030]ns	[0.0014]ns
Share of regional photovoltaic and wind power installed capacity (MW)	0.990	1.004	1.003	0.983
	[0.0090]ns	[0.0178]ns	[0.0280]ns	[0.0134]ns
Public incentives from regional governments to RES (million €, t-1)	1.018	1.035	1.0287	1.0009
	[0.0054]***	[0.0094]***	[0.0165]***	[0.0086]ns
Objective 1 Regions' status	1.4560	0.554	0.498	1.597
	[0.9241]ns	[0.3907]ns	[0.4372]ns	[1.1634]ns
Regional government political colour (centre-right, t-1)	0.705	0.578	0.6269	1.004
	[0.0764]***	[0.1095]***	[0.2057]ns	[0.1641]ns
Net energetic import from abroad (TWh)	1.017	1.015	1.016	1.019
	[0.0057]***	[0.0103]ns	[0.0186]ns	[0.0082]***
Net energetic balance with other Italian regions	1.088	1.113	1.066	1.067
	[0.0189]***	[0.0323]***	[0.0407]*	[0.0251]***
Overdispersion	1.908	0.957	0.987	1.20