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Patterns of induced diffusion of renewable energy capacity: The role of regulatory design and decentralization

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Abstract

The paper adopts an epidemic model of innovation diffusion to investigate the influence of regulatory design on the market penetration of wind and photovoltaic energy production. In particular, we test whether the specificity of public incentives by technology and the level of decentralization of energy policy planning and of authorization procedures have influenced the pattern of diffusion of renewable energy technology. Data pertain to the Italian case between 1999 and 2010. Results confirm the existence of an S-shaped Bass diffusion process for RES technologies. We disentangle the contribution of several institutional factors to the diffusion of renewable energy innovations: liberalization of the electricity market, public subsidies, EU support to Objective 1 regions, decentralization of energy planning, complexity of authorization procedures, technology-specificity of incentive design. We also analyze the regional variability in diffusion patterns.

JEL code: Q47, Q48, Q42.

Keywords: Renewable energy, Bass model, induced diffusion, feed-in tariff, decentralization, energy planning, authorization procedures.

1. Introduction

The production of electricity from renewable sources (RES-E) plays a critical role in climate change mitigation policies, and has the potential to reduce energy dependence from fossil fuel imports and promote innovative activities. Incentives to RES electricity are thus legitimated on the ground of environmental but also energy security and industrial policy objectives.

In an ideal world, the government could address separately environmental externalities and R&D externalities of innovations through objective-specific instruments, as illustrated by Fisher *et al.* [17]. Real world RES policies, however, tend to take the form of multi-objective packages, simultaneously affecting a plurality of RES technologies (for a comprehensive review see IEA [18]). Financial support to research programs and to the construction of demonstrative plants is usually directed to a single technology. Incentives to general RES investments or to RES production, instead, are often designed within broader sustainability policies, and rarely focus on specific groups of technologies or plants size. This is certainly the case of Italy, where the technology-specificity of incentives has been gradually introduced and significantly increased only after 2005.

Using the installed capacity of wind and photovoltaic power in the Italian regions as indicator of diffusion, we aim at investigating:

- the shape of the diffusion dynamics for wind and photovoltaic energy technologies.
- the relationship between the diffusion pattern and the relevant policy interventions;
- the impact of regulatory design, in particular an increase in the technology-specificity of policy instruments, on the diffusion process.

Analyzing the time dynamics of the diffusion of solar and wind capacity, we empirically examine also the influence of further institutional determinants, such as the decentralization of energy planning responsibilities, on the deployment of RES.

An extensive literature on the dynamics of innovation diffusion, including several recent studies pertaining wind and photovoltaic energy technologies, finds evidence of Bass S-shaped diffusion patterns. Using the biologic metaphor of epidemic contagion, the Bass model assumes that the diffusion of a new technology initially depends on the initiative of early adopters, whereas an imitative process fuels a subsequent phase of expanding market penetration up to the saturation of the full market potential. It presents an asymmetrical S-shaped distribution, with a higher diffusion rate of the new technology or product at the beginning of the process, resulting from a spontaneous market appreciation of the innovative content. Since its appearance in 1969 (Bass [1]) the model has been adopted in a considerable number of studies in the area of innovation diffusion and product growth (a review of conceptual issues and advances is provided by Mahajan *et al.* [2]). The S-shaped family of diffusion patterns derived from the logistic, Gompertz and other specifications has been broadly applied to commercial products and technologies. According to the classification of Rao and Kishore [3], within the economic literature we find diffusion models applied to (i) ex-post assessments of the general spread of an innovation (Bass [1, 4], Bewley and Griffiths [5], Desiraju *et al.* [6], among others); (ii) investigations of the role of pricing as a determinant of diffusion (Bottomley and Fieldes [7]; Jain *et al.* [8]); (iii) studies aimed at technology and demand forecasting (Chow [9]; Anderson *et al.*[10]). A group of the first type of studies deals with the diffusion of RES technologies. Wind farms have been studied by Rao and Kishore [11] and Ibenholt [12] and the case of photovoltaic technology is investigated by the ex post assessment by Peter *et al.* [13].

Further recent applications of the Bass model explicitly link the pattern of the diffusion process to the presence of subsidies or other regulatory instruments. Among these are the forecasting studies of Guidolin and Mortarino [14] for solar photovoltaic electricity (PV) and the work of Davies and Diaz-Rainey [15] for wind energy. Diaz-Rainey [16] considers induced diffusion as an intervention that aims to alter the speed and/or the total level of adoption of an innovation by directly or indirectly internalizing positive and/or negative externalities. Thus, the influence of policy stimuli, such as green energy incentives, drives a faster rate of early adoption and subsequently sustains the imitation process, and is external because is determined outside the population of innovators and imitators. This stream of literature acknowledges a need for further analyses considering the historical development of regulatory frameworks and other local determinants that may have delayed or accelerated RES diffusion in different countries. Our paper contributes to filling this gap.

We thus test whether a logistic or a Bass S-shaped dynamics for wind and photovoltaic energy technologies, of the kind emerged in the above mentioned studies, is confirmed in the Italian case and extend the analysis to consider relevant historical and institutional factors. Our prior hypotheses are that in Italy some modifications in the RES diffusion pattern may emerge as a result of (i) the evolution of authorization procedures to the deployment of new productive capacity; (ii) the decentralization of some energy planning responsibilities to the regional or local government level, that led to setting RES targets on the ground of quality and potential of local natural resources; and (iii) the evolution of regulatory design towards technology-specific incentives.

Section 2 briefly describes the regulatory framework for RES in Italy. Section 3 presents the econometric strategy adopted, and section 4 reports the steps of the econometric analysis and the results. Section 5 discusses the policy implications emerging from the quantitative analysis and concludes.

2. The evolution of RES incentives and policies in Italy

2.1 Designing the market

Setting aside the structural disadvantages of RES technologies relatively to conventional electricity generation based on fossil fuels (such as the scarcely predictable intermittency and variability in space of renewable energy sources), in Italy the electric market structure has long represented the main barrier to a large scale deployment of RES-E.[1] The vertically integrated monopoly by the national operator ENEL lasted from 1962 to 1999, year of the market liberalization.[2] The incumbent maintained a substantial share of the total production (not exceeding 50 percent), but new operators were allowed to enter in the electricity market. A mechanism of quota obligations was applied to renewable energy sources and coupled to a green certificates trading scheme that constrained big suppliers to cover at least 2 percent of their production with green energy, with an yearly increase of 0,35 percent (AEEG [19]).

Evolution of RES incentives: towards technology specificity

The first form of RES incentives introduced in Italy was a feed-in tariff (CIP6) introduced in 1992. It applied to a variety of plants, many of them assimilated to renewable sources but *de facto* generating electricity from waste or fuels belonging to the supply chain of hydrocarbons, such as residuals from refineries. Based on past data and extrapolations to 2020, estimates by the national association of renewable energy producers (APER [20]) show that the 'quasi-renewable' part of (controversially) subsidized energy production captured 83.8 percent of the total amount of the electricity subsidized by the CIP6 feed-in tariff. In 1999 the eligibility of RES plants for the CIP6 scheme was partially restricted and the systems was almost completely replaced by a tradable green certificates scheme with quota obligations (TGC), to which most of the RES plants commissioned after April 1, 1999 have been submitted. The amount of the subsidy per unit of renewable energy assigned by the GSE[3] to each RES source was repeatedly updated.

A discrete step forward in the differentiation of incentives by technology was the introduction of the so-called *Conto Energia* (CE)[4], the new feed-in tariff responding to the European Directive 2001/77/CE, exclusively targeted to photovoltaic plants. Additional criteria within CE contribute to differentiate by

[1] Hydroelectric and geothermal energy have historically been a relevant RES-E component in the Italian energy mix. They cannot be considered innovative. The potential for hydro capacity (concentrated in northern Italy) has been almost entirely exploited. Geothermal energy can be extracted by means of different technologies, some of them (high enthalpy) with a long history and not subsidized because of their high environmental impacts, other (combined closed medium and low enthalpy) very innovative but still at an early phase of development.

[2] National decree n.79, March 16, 1999.

[3] *Gestore Servizi Energetici*, the public company that manages the support to renewable electricity.

[4] National decree July 28, 2005.

technology the intensity of incentives. The level of the feed-in tariff depends on the date of activation, on the size of the plant, and on the level of landscape integration (with higher incentives to plants of lower visual encumbrance).

A further measure, the Global Tariff, or *Tariffa Onnicomprensiva*, again based on a feed-in mechanism, was introduced in 2008. It is dedicated to very small size plants, and for this reason its overall scale, in terms of installed MW and relative expenditure, is almost irrelevant compared to that of previous schemes. In 2012, year of full implementation of this instrument, the overall amount of resources for the Global Tariff has been of 0.4 billion euro. The total expenditure (in 2011 billion euro) for the CIP6 scheme for the period 1998-2020 is estimated to be around 23 billions, and that for the TGC scheme of 9 billions. For the photovoltaic CE the annual expenditure has been modified over time and a reliable aggregate estimate cannot be made due to the instability of expenditure constraints (APER [20]). A theoretical maximum annual expenditure level for the photovoltaic CE will be reached in 2016, according to APER estimates, at around 6.8 billion euro, but due to the actual re-design of financial budgeting constraints the expenditure on CE is likely to be the less stable, as it is the one triggering the highest negative impacts on Italy's balance of trade.

The relative weight of TGC schemes with respect to feed-in tariffs has been progressively decreasing since 2005. Conversely, the complexity of the incentive system has been increasing, with the introduction of a single technology-specific instrument for PV energy together with separate feed-in tariffs for small capacities, of the so-called Guarantee of Origin (a certificate for imports of RES electricity), of voluntary instruments such as the international Renewable Energy Certificate System (RECS), and of fiscal rebates. All of these policies are intertwined and interacting (e.g. PV deployment of new investments redirected from TGC to the most profitable and/or stable subsidization at each re-modulation of the CE settings). A complete and systematic assessment of energy and environmental policies impacting upon RES diffusion would also require to consider environmental taxation and the EU Emission Trading scheme. Our purpose however is not providing an integrated impact assessment of all these measures, but rather evidencing how efforts by policy makers have been progressively directed to raise the level of specialization of incentives by RES technologies.

Centralized versus decentralized governance: Authorization procedures and energy planning

The diffusion of RES electricity production is influenced also by the presence of nonmarket barriers, such as the duration and structure of local authorization procedures for power plants, as highlighted in the case of Spain by Iglesias *et al.* [21]. In Italy, a regionally differentiated and fragmented regulatory structure was announced to be reformed through the introduction of a rationalized scheme for the authorization process. In 2003 Italian regulations pertaining the installment of RES power plants adopted the so-called *Autorizzazione Unica* (UA, Unified Authorization) defined by the EU Directive 2001/77/CE. 'Unified' within this context does not mean that a single agency is involved in authorizing electricity production, but that the legal responsibility of the overall procedure is assigned to a single public actor, in the presence of multiple roles and actions required from a plurality of actors (health authorities, local environmental agencies, fire brigades, forestry commission, and so on). In the absence of national guidelines, an absolute lack of coordination led to a variety of different regional settings.

To become operational, this reform had to be completed by the approval of a set of national guidelines. This final act was repeatedly delayed, thus maintaining for more than seven years authorization procedures very dissimilar by region. While waiting for national guidelines (which arrived in 2010), regional governments formulated normative instruments for the AU, which in several cases had then to be modified to comply with the subsequent national framework. Not all regions implemented the AU. The power to authorize new RES capacity is not necessarily assigned to the same level of government in different regions, and the competence in some cases is shared among more than one level. The time and effort required to obtain authorization for installing new RES capacity varies widely, as a consequence, among regions.

Authorization procedures are not the only institutional characteristic of RES governance to be geographically variable. The assignment of competence over the design and approval of energy plans is another important component of the decentralization process. The shift from national to local governments energy plans has the effect of disclosing information on the spatial distribution of both environmental potential and public and political acceptance of different RES technologies and thus help the market to locate investments in renewables. In addition, the heterogeneity in the implementation of decentralization of powers over energy planning reveals the capacity and/or institutional constraints of different regions in managing the procedures that RES investments have to face.

The heterogeneity in the regulatory an institutional conditions faced by the energy market forces in decentralized governments is a factor, generally overlooked, that may significantly contribute to refine the analysis of the spatial dynamics in the diffusion of RES technologies. The status of implementation of the Unified Authorization procedure and of decentralized energy planning for all Italian regions are reported in Table 1.

Table 1: Implementation of Unified Authorization procedures and regional energy plans in the Italian regions (source: own elaboration from regional laws and Nextville - www.nextville.it).

NUTS2 regions	Description	Level of government responsible for authorization of RES	Year of implementation of regional rules for UA	Year of introduction of regional energy planning
ABRUZZO	Simplified procedure for photovoltaic between 20 and 200 kW installed on buildings and within urban landscape	NUTS2 (Regions)	2008	2009
BASILICATA	AU only partially adopted. Authorization regulated by preexisting regional law	NUTS2 (Regions)	2011	2010
CALABRIA	AU adopted then rejected for incompatibility with national guidelines. Excessively simplified requirements for plants <1MW. Authorization facilitations to public investors	NUTS2 (Region)	2010	2005
CAMPANIA	AU adopted, with simplified requirements for photovoltaic plants < 100kW or <5MW for liquid biomass plants	NUTS2(Region) NUTS3 (Provinces) only for plants <1MW (3 or 5MW for liquid biomasses and biogas	2011	2009 (draft).
EMILIA ROMAGNA	AU not adopted	NUTS2+NUTS4 for plants >50MW NUTS3 for plants <50MW	-	2007
FRIULI VENEZIA GIULIA	AU not adopted	NUTS4 for plant <10MW NUT4+NUTS3 for plants 10-25MW NUTS3 for plants 25-50MW NUTS2 for plants >50MW	-	2007
LAZIO	AU adopted	NUTS2-NUTS3	2008	2008
LIGURIA	AU adopted with additional zoning for wind authorizations	NUTS3	2011	2003
LOMBARDia	AU adopted	NUTS3 (with exclusion of Hydro and geothermal)	2003	2007
MARCHE	AU not adopted	NUTS3	-	2005

MOLISE	AU adopted	NUTS2 for plants >1MW NUTS3 for plants <1MW	2008	2006
PIEMONTE	AU not adopted	NUTS3	-	2009
PUGLIA	AU adpted	NUTS2	2011	2007
SARDEGNA	AU partially adopted	NUTS3	2009	2006
SICILIA	AU not adopted	NUTS2	-	2009
TOSCANA	AU adopted	NUTS3 for Wind 100kW-1MW NUTS2 for Wind >1MW NUTS3 for photovoltaic >200kW NUTS3 for biomass >200kW NUTS3 for Hydro >100kW NUTS3 for biogas>250kW NUTS2 for geothermal	2005	2008
TRENTINO ALTO ADIGE	Not adopted	NUTS3	-	
UMBRIA	AU adopted	NUTS4, NUTS3 since 2008	2004	2004
V. D'AOSTA	AU adopted	NUTS3=NUTS2	2005	2003
VENETO	AU adopted	NUTS4 for PV<20 kW; wind <60kW; 100kW for hydro; 200kW for biomasses; 250kW for biogas	2008	

3. The econometric strategy

The proportion of additional RES installed capacity from *t* to *t+1,* relative to a certain saturation level, depends on the capacity already deployed, and on the residual market space. In the original Bass model an additional parameter *a* represents the influence of innovators (early adopters) on the pattern of diffusion. In the RES case, Davies and Rainey [15] postulate that the adoption of innovation is substantially driven by the existence of policy stimuli, so that *a* subsumes all of the exogenous factors inducing RES diffusion, including the effect of incentives on the preferences of RES adopters. The basic Bass model can be written as:

$$D_{t+1} - D_t = [a + bD_t] \cdot [1 - D_t] \qquad (1)$$

A simple linear model fits this structure. Equation (1) can be rearranged assuming a panel structure. Our unit of analysis are Italian NUTS2 regions between 1999 and 2010. Being D_{it} the level of diffusion of the PV and wind capacity of region *i* at time *t*, the basic specification becomes:

$$S_{it} = a_i + b_i D_{it} \qquad (2)$$

The diffusion D_{it} is here considered as the proportion of wind and PV deployed capacity (in MW) with respect to the total installed capacity from all forms of electricity generation within region *i*. The term S_{it} is the switch: the proportion of capacity of non wind and PV capacity that is switched to wind and PV, during period *t* in region *i*. The term *a* can be specified assuming that it reflects the region-specific policy inducement on the diffusion process. Building on the formulation of Davies and Diaz-Rainey [15] we add further variables in order to disentangle policy-driven effects from the basic innovation coefficient. We use either time invariant characteristics or time variant variables (mirroring the evolution of institutional factors and differences across regions). The full model is:

$$S_{it} = a_i + b_i D_{it} + c \cdot \gamma_{it} + d \cdot \eta_{it} + e \cdot \lambda_{it} + f \cdot \pi_{it} + \mu_i + \varepsilon_{it} \tag{3}$$

Equation (3) states that the shift of wind and photovoltaic capacity in year *t* (t_0 = 1999, the year of the liberalization of the Italian electricity market) depends on the level of diffusion within the region, on the presence in the region of RES incentives on capital costs (γ), on the introduction of technology-specific incentives to production (η), on the status of regional energy planning (λ) and on the presence of rationalized authorization procedures of new RES plants (π).

The quantity of lump sum transfers made by the European Union through the European Regional Development Fund for the development of renewable energies over the programming period 2000-2006, reported in Franci [22], has been initially considered as a suitable source to build a continuous and monetary scale for the γ variable. Due to the difficulty to find a complete and detailed coverage for the entire time period we opted for introducing in the model a dummy coded variable γ for regions qualifying for the Objective 1 status, which benefitted from higher transfers to the renewable energy sector.

The technology-specificity of incentives to RES generation in Italy increased, with respect to the generalized green certificate scheme designed in 1998, with the introduction in 2005 of the CE feed-in premium scheme restricted to photovoltaic (periodically revised and still in force). We thus identify a discontinuity in the technology-specificity of incentives between the 1997-2004 and the 2005-2010 phase through a dummy variable η. Its role is to disentangle the policy inducement coefficient *a* from the impact of the introduction of the CE photovoltaic program.

The presence of decentralized energy planning λ and of enhanced authorizations procedures π is coded as well as pre/post discontinuities due to changes in the institutional setting: a region specific periodization is introduced via dummy variables that take the value of 1 starting from the year of implementation of regional energy plans (λ) and of the Unified Authorization (π).[5]

4. Results and discussion

Our econometric analysis follows some of the steps in Davies and Diaz-Rainey [15]. We intentionally maintain our analysis as parallel as possible to theirs so as to enable a comparative assessment of the estimates of the inducement and diffusion coefficients in the two studies. We do so for two main reasons:

(i) we aim at checking if the diffusion pattern of the joint couple of wind and photovoltaic technologies matches the Bass process already identified for the wind technology.

(ii) Our geographical units are NUTS2 regions, differently from the country-level observation of previous studies such as [15]. The above mentioned study has the merit to identify the link between diffusion performances and the structure of national public incentives. We rather focus on the role of decentralized decisions, norms and institutional practices that may constitute barriers or inducements to the development of wind and photovoltaic energy production. Controlling for these observable local factors, we investigate whether the adopted geographical scale of our panel analysis allows us to reach a better or worse goodness of fit, and whether the change in the spatial scale leads to confirm or disconfirm the adequacy of simple models such as S-shaped diffusion curves.

Table 2 reports the results of the panel analysis and the group of estimated models. The first column refers to regression I, obtained through a fixed effect simple model: the values of the intercept and the diffusion level (both positive and significant) offer a first evidence of a Bass diffusion pattern. Both the diffusion parameter (0.1839) and the policy inducement parameter (0.0038) are quite close to the results obtained on the European-wide sample used by Davies and Diaz-Rainey, respectively 0.186 and 0.004.

The second model (II) is a pooled OLS, conceptually similar to the previous one, explicitly identifying region specific effects captured by the set of region specific dummies. The value of the intercept in this model can be interpreted as a component of the inducement effect shared among all regions, whereas the values of parameters of region specific dummies (significant only for Trentino Alto Adige, Lombardia and Emilia Romagna) disentangle the differences between the policy inducement of a specific region and the average one (the omitted group adopted as a baseline is the region Marche). Considering single region series, our regression II confirms the presence of a Bass pattern for RES diffusion in Sicily, Sardinia, Apulia, and Emilia Romagna.

The regression model III is obtained via a Hausman-Taylor estimator. It relaxes the assumption of complete uncorrelation between regressors and the idiosyncratic error component. Since the rapid diffusion of the RES capacity itself might have contributed to the urgency of developing energy planning at the regional level, we treated the relative dummy as an endogenous variable, in order to limit the possible effect of reverse causality that would result in biased estimates. While models I and II, following the approach of [4], do not explicitly control for institutional factors, our model III uses the intercept to assess the influence of incentive policies on the diffusion process and allows us to disentangle the policy inducement effect on specific components (and periods). The fact that an initial diffusion component in III is still statistically significant and positive is a further result consistent with our theoretical hypotheses: the intercept represents the inducement effect in the initial period between the electric market liberalization of 1999 and 2005. The dismantling of market access barriers and the existing incentives may both have contributed to produce a Bass pattern.

Model III confirms that Objective 1 regions, which benefitted from capital cost subsidies from the EU, also exhibit a systematic increase in the value of the shift. The positive and statistically significant value of parameter *c* tells us that the introduction of feed-in tariffs for photovoltaic further contributed to the diffusion of photovoltaic and wind energy production.

Finally, a smaller but still positive contribution derives from the introduction of decentralized energy planning (parameter *e*). The modification of the authorization processes, instead, does not seem to influence the diffusion pattern.

The goodness of fit of models I and II is not exciting (values of the overall R^2 are respectively 0.31 and 0.32, roughly corresponding to the figures in Davies and Diaz-Rainey's analysis [15]). The substantial similarity of results between ours and that study, both in terms of overall goodness of fit and of the diffusion parameter, suggests that the two bundled technologies follow a diffusion pattern that is consistent with the specific wind and photovoltaic curves. It also suggests that the diffusion dynamics at the subnational level of Italian regions mirror the same patterns prevailing at the national level in European countries.

Table 2: Estimation results

	I	II	III

a_i *Intercept*	.003874 (.001)***	0,01281 (.0259137)***	0,00109 (0,0015518)**
b *Diffusion level*	.183914 (.025)***	0,18391 (.0041769)***	0,14897 (0,0221931)***
c*Subsidies on capital costs*			.0062429 (.0023308)***
d *Technology specificity*			.0047695 (.0027992)*
e*Energy planning*			.0044238 (.0028181)*
f *Unified authorization procedures*			-.000733 (.0029255)
Abruzzo		-0,01577 (0,00604)*	
Basilicata		-0,00117 (0,006856)	
Calabria		-0,00617 (0,005901)	
Campania		-0,01514 (0,006241)*	
Emilia		0,00937 (0,005902)*	
Friuli		-0,01056 (0,005902)	
Lazio		-0,01073 (0,005902)	
Liguria		-0,01231 (0,005902)	
Lombardia		0,01148 (0,005903)*	
Molise		-0,00477 (0,006012)	
Piemonte		-0,0107 (0,005903)	
Puglia		-0,00655 (0,006001)	
Sardegna		-0,00851 (0,005998)	
Sicilia		-0,00400 (0,005952)	
Toscana		-0,01058 (0,005901)	
Trentino		0,00952 (0,005901)*	
Umbria		-0,00958 (0,005901)	
Val d'Aosta		-0,01244 (0,005903)	
Veneto		0,00946 (0,005902)	
R-square within	0.1741		
R-square between	0.8055		
Overall adjusted R-square	0.3203	0.3147	
Sigma u_i	.00412703		.0043809
Sigma e_i	.01504184		.01452401
Rho	.07000887		.06985266

*, **, *** Significance levels respectively at 0.1, 0.05 and 0.01

5. Conclusions

This study, through the empirical observation of institutional facts in the Italian context, allows us to identify the link between energy policy design and the RES diffusion process, and to evaluate the magnitude of the policy inducement generated by different sets of instruments. The results carry policy implications that may be replicable on a more general scale.

We show that the early inducement effect may be explained as a joint impact of liberalization and of the co-existing CIP6 and TGC schemes. The Italian regulation evolved from a phase of support to RES through a feed-in tariff scheme (1992-1999), to a phase of overlapped feed-in tariff and TGC, with open eligibility to all RES technologies (1999-2005). The TGC introduced some differentiation in the intensity of subsidization to different RES technologies. The periodization based on the subsequent reform of incentives shows that a further statistically significant support to the diffusion of wind and photovoltaic appears with the introduction of markedly technology-specific incentives (CE). This first periodization is shown to hold, with an increased inducement effect shared across Italian NUTS2 regions. Our analysis of the historical development of the regulatory framework suggests that the design of incentive packages is the result of a complex (and truly imperfect) process of institutional learning about the functioning of and interaction among policy instruments [23].

In addition our panel analysis points out that region specific periodizations can explain a further component of the observed heterogeneity of the diffusion patterns. The devolution of energy planning power to local governments generates a positive inducement effect, comparable in term of magnitude to the contribution of the technology specificity factor. The design of decentralized regional energy plans implied that a local learning process was set in motion and percolated among local actors, as biophysical and techno-economic knowledge had to be integrated in the assessments of feasible RES targets. Drafting regional energy plans activates wide interdisciplinary applied research on the territory environmental potential in order to obtain approximate estimates of the regional producibility. Part of this knowledge is the same that can help firms to properly locate plants, especially for the efficient exploitation of wind power.

Finally, we note that the incentives on capital costs destined to regions with competitive disadvantages reveal, despite the less dynamic economic environment, an impact that is considerably higher than the intercept and than the effect attributed to decentralization of energy planning. Nationally set RES incentives, in Italy, tend systematically to focus on the production phase. A subsidized market price thus becomes the main way to compensate for all the costs borne by RES energy producers also in term of capital costs and nonmarket barriers [25].

The granularity of serial data on deployed RES capacity and the length of the available observation period at present force the analysis to leave out a set of other potentially relevant drivers. Besides increasing the technology specificity of incentives, for example, RES policies in Italy since 2005 have tended to reduce the weight of instruments based on the regulation of quantities, such as TGC, in favour of instruments that set prices, such as feed-in tariffs [24]. The latter impose a lighter burden in terms of operational and administrative costs, and may therefore contribute to a faster diffusion. Including in the analysis the impact on RES diffusion of transnational spillovers of non-harmonized incentive policies [26] could be a further interesting development.

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