FONDAZIONE ARISTIDE MERLONI

ECONOMIA MARCHE **Journal of Applied Economics**

Vol. XLIII, No.3, Dicembre 2024

The deployment of electricity smart meters in Italy: an econometric analysis on italian municipalities

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Abstract

Sustainability has now become a watchword in the policies that countries are developing in any field. Electricity is a sector that is undergoing profound changes as a result of the introduction of new technologies and renewable sources. The revolution starts not only from a change in the energy sources used, but also from a reduction in energy consumption and increased awareness by end users. In order to be able to do this, a tool that acquires fundamental importance is the smart meter.
This work aims to analyse the diffusion of second-generation electricity smart meters in Italy. Italy is a pioneer country in the installation of smart meters, counting that it is already replacing first generation meters with second generation ones; therefore, a more in-depth analysis of the level of diffusion and differences at a territorial level is necessary.
Considering the Italian territory, the level of replacement of smart meters differs among regions and, also within the same region, the provinces have different installation rates. The objective of the research is to explore which characteristics and elements have mostly influenced the differences in the replacement rates of municipalities.

JEL Classification: L51, O12, O52, O57

Keywords: *Electricity smart meters, European Regulation, Technological evolution, Energy efficiency, Deployment, Italian municipalities*

1. Introduction

The aim of this article is to identify what are the socio-economic and geographical factors that impacted on the decision of substitution of first-generation smart meters with second generation ones in Italy at a municipal level. Smart meters can be considered as a fundamental technology in the electrical grid that will increase efficiency in the entire system. Italy is considered around the world a pioneer in smart meters deployment bearing in mind the great results achieved with the installation of the first generation. With technological evolution first generation smart meters were no more suitable in the new context and a more advanced generation has become desirable. The electrical grid has changed and also its value chain with the introduction of technological innovations. Smart meters, that produce data about the energy consumption of the household, brought benefits to society, citizens and system operators. Data availability enables a more informed customer who can implement measures to increase energy efficiency and a more flexible system that will facilitate the prediction of required energy volumes and the introduction of renewable sources.

The literature has analysed drivers that lead installation patterns of smart meters in different countries of the world. The European case was analysed by the literature, it represents an interesting case because even though the legislation is the same for all Member States, the stage at which they are, varies considerably from country to country. Much research has been done to determine what are the factors that impact on smart meters' diffusion and what can be done to incentivize the adoption. Considering that it's a technological innovation that involves customers, policymakers, firms and civil society organizations, the cultural and social elements should be considered when determining the drivers that impacted on the smart meters' deployment so each country presents a model of development of its own, although some common drivers could be found. The European case is a perfect example because, even if there is the same legislation at communitarian level, the deployment across countries is different because each country adopted a different regulatory framework considering the heterogeneity in the environmental, technological, regulatory and cultural context.

From the literature it emerges the important role of the regulatory framework in the deployment of clean energy technologies.

Drivers in the deployment have been analysed in different countries with a comparison at state level or regional one, while this elaborate focuses on differences across municipalities and other territorial aggregations in the substitution rate of second-generation smart meters.

Considering that substitution level has reached across the Italian territory a satisfactory level, it's possible to make an analysis "a posteriori" to comprehend what influenced the installation decisions. The paper will analyse the substitution pattern of the largest Italian distributor e-distribuzione that covers almost the entire territory to understand if the specific characteristics of each municipality and other geographical factors had an impact on replacement decisions. e-distribuzione is the Italian historical distributor as well as the market leader in the distribution sector of the electricity market.

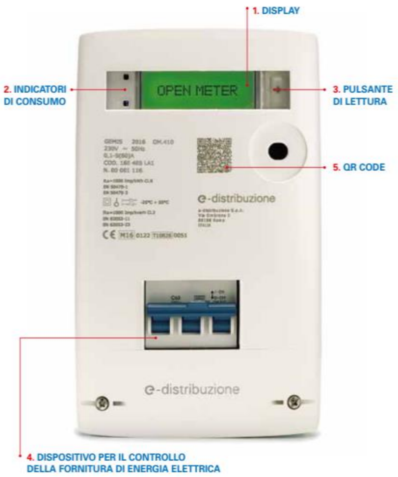
The empirical analysis is carried out considering Italian municipalities covered by e-distribuzione and their socio-economic and geographical characteristics. A regression analysis is done with STATA, utilizing a dataset comprehensive of the substitution level and the characteristics of the municipalities. The regression has the aim to demonstrate the factors that explain differences in the installation level across municipalities, controlling for a comprehensive battery of indicators.

The paper is organized in two sections, in the first one there is an analysis of the literature to understand the importance and the functionalities of these instruments and the context in which they are part, then the focus will be on the drivers that impacted on substitution decisions and the level of deployment in Europe, subsequently the Italian case is analysed, which is already replacing first generation meters with second generation ones; the second section is about the empirical analysis which is carried out considering Italian municipalities covered by e-distribuzione and their socio-economic and geographical characteristics.

2. Smart meters: definition, benefits and context

A smart metering system is defined as "an electronic system that can measure energy consumption, providing more information than a conventional meter, and can transmit and receive data using a form of electronic communication" by the European Directive 2012/27, known also as Energy Efficiency Directive. As highlighted by the definition, smart meters are systems that allow remote reading and remote management of measuring devices in different sectors: electricity, gas and water. From now on, the focus will be on electricity smart meters, considering the large diffusion they have, an example of this device is shown in Figure 1. The increasing attention over the past few years in smart measuring systems is explained by the necessity of moving towards a decarbonised economy, it should be also underlined that the substitution of electromechanical meters with electric ones represents the first step in the process of empowerment and evolution of the electrical grid (J. Batalla-Bejerano et al., 2020).

Figure 1 - e-distribuzione's smart meter



Source: e-distribuzione

Smart meters could also contribute to create a more sustainable environment and "Smart Earth" as highlighted by Bakker (B.K. Sovacool et al., 2021, p. 2) where Information and Communication Technologies (ICT) together with digitalisation and Internet of Things (IoT) can help in transforming consumer behaviour, monitoring the environment and changing the governance.

Smart meters are an important part of a system that includes many actors, data communication, policies and regulations so it's a quite complex setting and they fit inside the smart grid. The electricity grid was for long term considered as a passive element, in the classic value chain the energy flows from generation to transmission, distribution and at the end the customer was reached. However, over the past few years a more complex situation has arised because of the new challenges introduced by the technologies, the new role of the customers, the renewable sources and distributed generation. The value chain changed because it is no more linear but it revolves all around a platform.

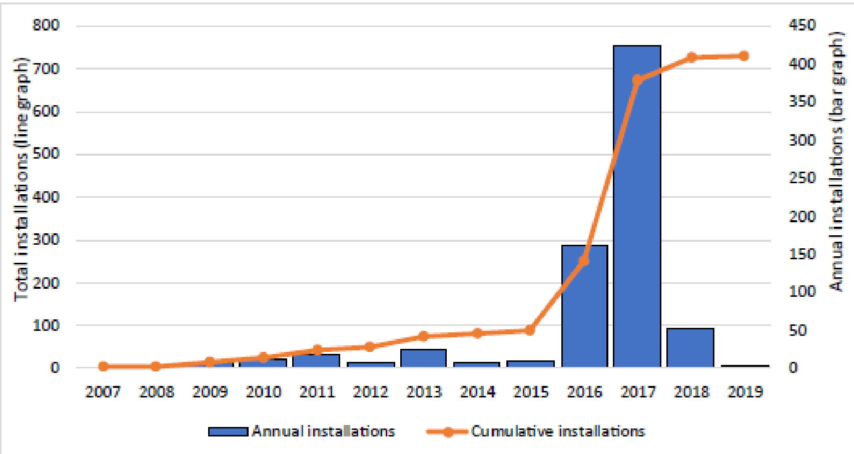
The electricity system is now decentralised because of renewable energy sources (RES) which changed completely the energy sector, first of all because it's possible for customers themselves to produce energy, so there is distributed generation, and then because a new challenge was introduced: the difficulty in

predicting the volumes dispatched in the grid.
Smart meters have a fundamental role in the grid to guarantee the connection, the exchange of data and the integration of new actors in the network, they represent at the same time the first step in building the smart grid and a key element in the development (S. Giest, 2020).
Smart meters have multiple purposes and an active role in the energy transition. The devices are designed to allow energy consumption reduction, to shift energy use from peak periods where the energy is more expensive to produce because more costly generation technologies have to be used (J. Batalla-Bejerano et al., 2020) and so customers save money, to empower the customers giving them more awareness about their individual consumption thanks to information provided and to make more informed decisions because data driven.
Despite the numerous benefits, smart meters have also raised concerns, like privacy, health, security issues. The objectives at stake are different among the stakeholders: suppliers want to reduce general management costs associated with manual readings and improve services offered to customers; the operators in the transmission system and distribution network wish to benefit from a more flexible demand to increase the penetration of low-carbon technologies; the governments want to reach carbon reduction targets; end-users want to reduce their electricity bills and become more aware of the energy consumed (E. McKenna et al., 2011).
When speaking about energy transaction, the focus is not only on the switch to renewable sources, but also monitoring and reducing the energy consumption is fundamental to create a sustainable energy value chain. Raising public awareness about correct behaviours to limit energy consumption is a key element.

2.1. The drivers of Smart Meters diffusion in Europe

To understand the level of smart meters diffusion in Italy, it is important to investigate the drivers that lead the installation decisions in the European territory. Smart meters are a technological innovation; patterns of diffusion for technological innovations in several fields have been studied. However, smart meters represent a particular novelty: they involve customers, but the level of awareness is low, additionally the institutional and regulatory framework have an important role in determining the level and speed of adoption (M. Rixen et al., 2014). Innovations in highly regulated industries like the electric power industry, are influenced by public policy and regulation determines the level of deployment of the technology by enabling or hindering the adoption. It could be considered as one of the largest household electricity transitions in recent years, taking into consideration the level of coverage reached by this technology only in a few years as shown in Figure 2.

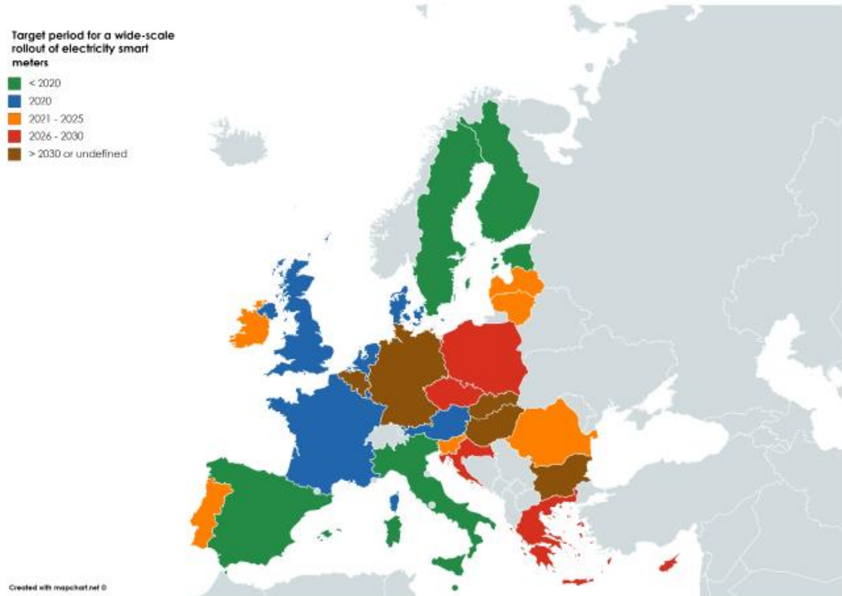
Figure 2 - Cumulative and annual smart electricity meter installations across 102 programs (in millions)



Source: Sovacool et al. (2021)

If the policy is compulsory and with a clear objective, it sends a clear message for the need and the importance of smart meters to all the stakeholders involved. The regulation should be stringent and certain because the innovation implementation is connected to investments that depend on a regulatory framework that will remain the same for a certain amount of time. Investing in smart meters deployment means taking risks, if not properly assisted by an adequate plan to recover costs and that assures benefits to stakeholders, because of the high level of required resources. The European Union in recent years has developed several regulatory instruments to promote the large-scale roll-out of smart meters. It's important to highlight that Member States are at different stages of the deployment and to reach the objective of climate neutrality by 2050, it's important that each country is on the same page.
In each State, the regulatory approach is different because it's determined by the electricity market structure. The number of DSOs (Distribution System Operator), their size and the degree of competition among the market players impact on the guidelines and the incentives necessary to stimulate smart meters deployment. In Germany or in the UK for example, the market is characterized by the competition and drivers to promote smart meters deployment are surely different from the ones of Portugal with a single DSO or Italy where there are several DSOs which are not subject to market competition.
The drivers of such a success in smart meters deployment in speed and volumes in certain States are linked to pragmatic reasons and not only by climatic and environmental motivations. The operators in the market are able, thanks to smart meters, to save costs because of the remote reading and they are also a tool that can be utilized in certain situations, like households who don't pay their bills to disconnect the electricity service.
Smart meters deployment was different from other technology forcing policies because they involved for the first-time customers, since the tools were installed in their houses, together with policymakers and companies. The companies in charge for the roll-out didn't make resistance because of the problem-solving potential and the potential cost-savings and smart meters are a complex technology that are strongly detached by the electromechanical meters, so new knowledge was required for energy companies with many issues arising (F.W. Geels et al., 2020).
The European Union set the initial target in 2020 giving also the experience and the knowledge gained from the implementation of smart meters in the first movers in this market: Italy, Sweden and Finland that by the time of the Third Energy Package already finished their installation (of first generation).

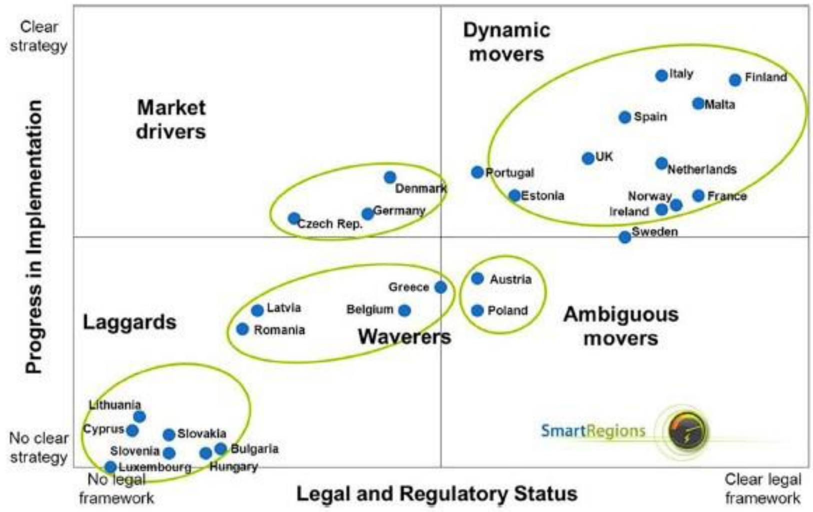
Figure 3 - Smart meters rollout in Europe



Source: European Commission "Benchmarking smart meter deployment in the EU", 2020

In 2018, as it's possible to see from data reported in the Benchmarking report and Figure 3, only Estonia, Finland, Italy, Spain and Sweden reached the target of 80% coverage by 2020. Smart meters deployment is driven by different forces across European Union countries, nevertheless the regulation has a very important role. Leaders in the deployment of smart meters like Italy, Finland, Sweden and Spain, that in Figure 4 are depicted as "dynamic movers", are the countries that have a clear legal framework that reduces uncertainties and address the deployment barriers in a clear way.

Figure 4 - Smart meters programs in European Union



Source: Geels et al. (2021)

2.2. The Italian case: first and second generation roll-out

Italy represents a very interesting case because it is a pioneer in smart meters installation worldwide (R. Van Gerwen et al., 2006).

To understand what were the main drivers that led to the success of this country it's important a brief overview of its history.

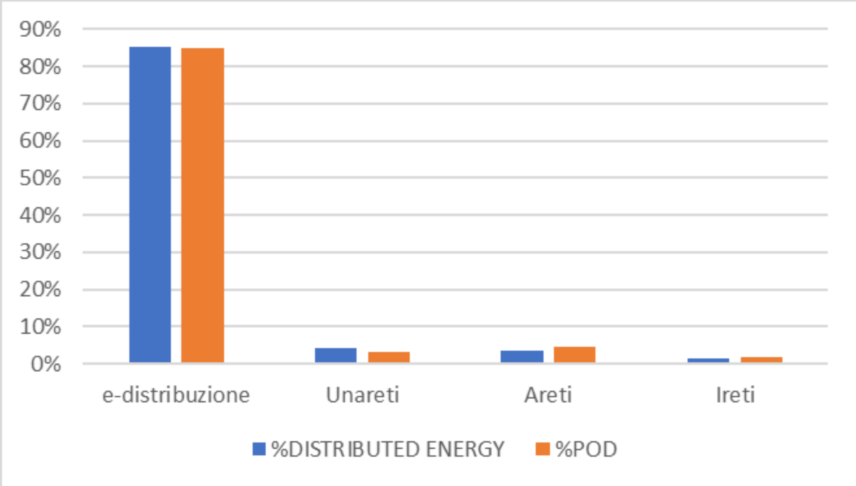
The national electricity system has long been under State management, starting with the establishment in the 60s of ENEL, which was responsible for all stages of the value chain. In the 90s the liberalization in the generation and supply activity started, while distribution and transmission remained a natural monopoly because of the high cost that should be sustained to double the infrastructure.

In Italy DSOs, which are regulated entities, are responsible for smart meters installation and they are also the owners. In the past DSOs were part of vertically integrated firms, but with the liberalisation in generation and supply activities, the European Directive 2009/72/EC provided the legal unbuilding for DSOs i.e., a separate legal entity for the distribution activity should be established[1]. In Italy the 4 biggest DSOs, represented in Figure 5, cover 94% of the total distributed power, so Italy can be categorized as a country with medium concentration.

The dominant DSO which is also the leader and is responsible for more than 80% of the distributed power is e-distribuzione and there are several smaller DSOs, each one responsible for specific areas defined by the Authority. In Italy DSOs are the part in charge for the installation and ownership of smart meters.

[1] The largest Italian DSO Enel-distribuzione became e-distribuzione to not create confusion with the branch of Enel that operates in the supply unit (F. Carraro et al., 2021).

Figure 5 - Market structure of distributors



Source: Author's elaboration from ARERA's data

Italy is the first mover in Europe for smart metering deployment, it was the first country to introduce smart meters for low-voltage end-users. There were two phases in the deployment of 1st generation (1G) smart meters:

- 2001-2006: spontaneous phase started by Enel distribuzione with the "Telegestore" project which finished in this timeframe the installation of its smart meters in the Italian territory, Enel became the first utility deploying smart meters worldwide (R. Van Gerwen et al., 2006),
- 2007-2011: mandatory phase with ARERA Deliberation 292/06 for all the other distributors seeing the benefits of the roll-out made by Enel-distribuzione.

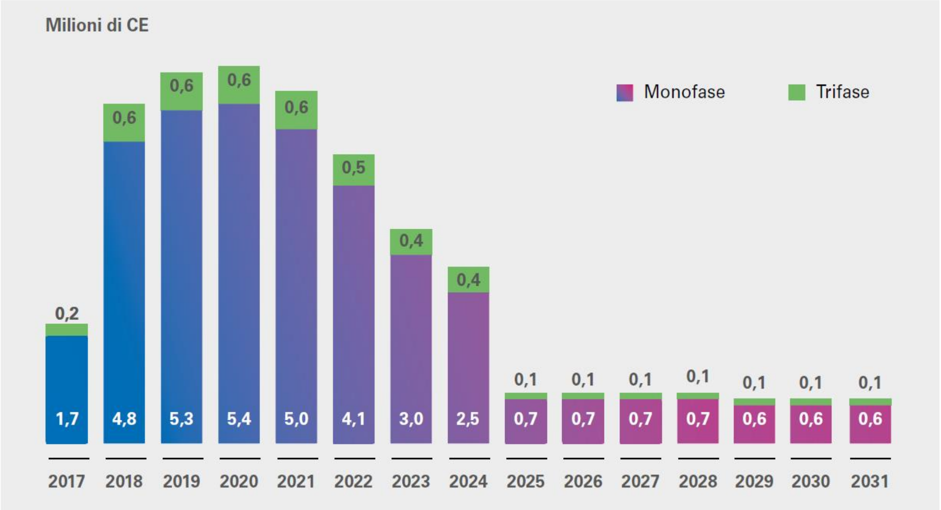
Enel decided at first to start the substitution of electromechanically meters with 1st generation smart meters because they wanted to save costs from personnel who was previously in charge of reading the old mechanical meters, to protect the point of delivery from frauds and energy theft, increasing the accuracy in the billing process, to reduce the cost for the intervention, errors in the measure that lead to wrong billing, peak shaving, demand side management. The company also pointed out that thanks to remote management, it's possible to avoid the emission of 30 thousand tons of CO_2 (C. Landi et al., 2014). Enel's decision to make in-company investment to introduce smart meters was done before deregulation of the energy market, so the company was still a state-owned monopolist.
In that period, the Italian electricity sector was moving in a liberalised market, smart meters had a pivotal role in accelerating the liberalisation because retailers were able to offer differentiated and competitive contracts.
In 5 years, Enel was able to reach its objective and unquestionably, the experience gained by e-distribuzione as first mover in the roll-out of 1st generation smart meters facilitate the development and installation of 2nd generation (2G) smart meters and implementation of new standards and functionalities also thanks to the availability of relevant data and the knowledge acquired. In fact, as first mover, e-distribuzione is able to predict in a reliable way the possible challenges and evolutions in the environment. Second Generation smart meters (2G) represents a disruptive technology with respect to 1G smart meters both for additional functionalities and their new role in the network. Despite the great innovation introduced with 1G smart meters, the evolution towards a smarter grid required additional functionalities to introduce benefits for all the actors involved in the value chain of the electricity system. The first-generation roll-out was a success covering 95% of the Italian low-voltage customer base and the new generation tries to create a greater customers' involvement. The substitution of smart meters became desirable because the 1st generation wasn't able to provide consumption data within 15 minutes and

design and technology frameworks became outdated because of the increasing functionalities and the rapid development in the technological panorama, in fact, they weren't able to communicate with in-home devices. Additionally, raising concerns of carbon emission and the need to use resources in a more efficient way are motivations that push toward substitution of smart meters in Italy.
"Chain 2" was introduced with 2G smart meters, it allows energy suppliers or authorized third parties to have access to non-validated consumer's energy consumption data. It's innovative because it's possible to directly communicate with customers' devices like smartphones and provide information directly to the customer to monitor energy footprint or to obtain innovative offers or energy efficiency services.
The 2nd generation Smart Meters have a life cycle of 15 years, so they should be able to support the transformations that will happen in the electrical system in the next few years. The new technology was welcomed by customers without resistance, unlike what happened in other European countries, and this facilitates the diffusion of the new devices.

3. Empirical Analysis

Italy represents a very interesting case because it started the 1st generation roll-out as first movers in the worldwide market and the country was able to reap benefits from this choice. Success was not easy to predict considering that smart meters are new technologies, and it was not said that customers would have welcomed the innovation without lowering the entire installation process. A combination of the right regulatory framework and a cooperative behaviour among stakeholders is a fundamental factor in the deployment's success for 2G smart meters, whose installation campaign is currently ongoing, as shown in Figure 6. The article analyses e-distribuzione's case because it is the largest DSO in Italy, it is in charge for the substitution of first-generation smart meters in almost all the Italian regions, only Valle d'Aosta and Trentino Alto Adige are excluded because other distributors are responsible in these regions. However, also in the regions covered by e-distribuzione there are some municipalities that have a different distributor like Milano or Roma, according to what established by the Authority.

Figure 6 - e-distribuzione substitution plan

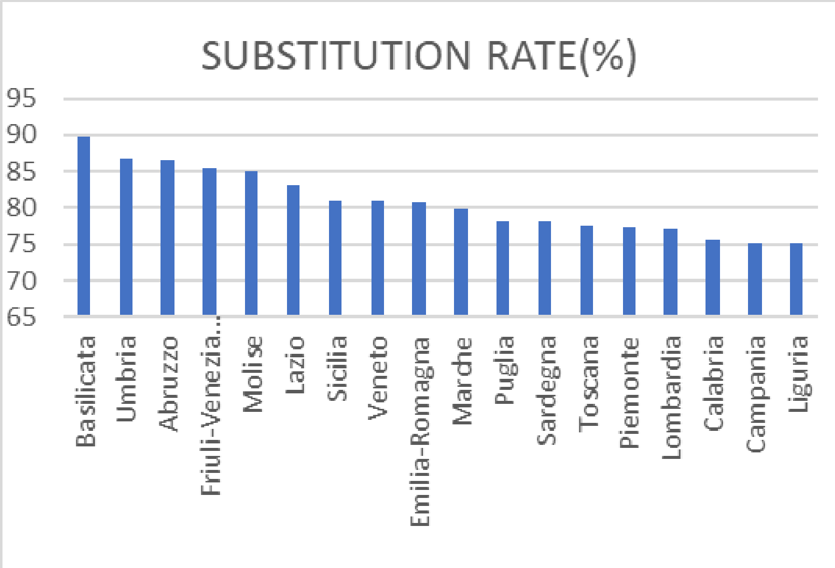


Source: e-distibuzione, 2017

To maximize efficacy and efficiency, the substitution is assigned to sub-contracted enterprises for homogeneous areas to limit logistic costs and guarantee the coverage in the overall territory.
The substitution is organized so that once the activity starts in a municipality, it continues until

completion.
At a regional level, as it's possible to see from Figure 7, the level of deployment is almost everywhere over 75% so it's a good result because every region is able to benefit from substitution.

Figure 7 - Data from e-distribuzione on deployment rate in Italy



Source: Author's elaboration

The regions with the highest deployment rate, more than 85%, are the ones with the lower surface area: Basilicata, Umbria, Abruzzo, Friuli Venezia Giulia and Molise. Looking at data at a provincial level, the province with the lowest level of substitution is Ascoli Piceno with a level of installation of second-generation smart meters of 52%.
Data are available also at municipal level and with a closer look to them, it's possible to see that not all the municipalities are at the same stage of substitution. Starting from this consideration, it's interesting to further investigate what are the reasons behind this choice. From a superficial analysis, the level of substitution is different also among municipalities in the same province, with municipalities that present nearly 90% of substitution and others that barely arrive at 50%. Considering that e-distribuzione has assigned the substitution to sub-contracted parties, it is reasonable to think that in neighbouring municipalities, that are part of the same province, the rate of deployment will be similar.
For this reason, an analysis of the characteristics of the municipalities is needed to understand the factors that impacted on the decision to substitute smart meters first in some places rather than in others. To conduct the analysis the DSO chosen is e-distribuzione, it's the only one that covers almost all the municipalities and so it allows a more in depth analysis because also the geographical factor could be analysed.
The analysis starts from data made available by e-distribuzione at municipal level, the aim is to understand what are the main drivers that lead the installation path in Italy. The research method chosen to conduct the analysis is multiple linear regression (with the OLS Estimation Method) to understand what is the effect that regressors have on the level of smart meters' substitution.
The dependent variable considered is the percentage of substitution of 1st generation meters with the 2nd generation ones in the municipalities. The regressors chosen to explain the differences in the deployment regard the socio-economic and geographical characteristics of the municipalities. These data were taken from "Atlante Statistico dei Comuni" and a unique dataset with all the municipalities and regressors was created.

The independent variables chosen to perform the analysis were data relating to number of resident populations, surface and also variables regarding the geographical characteristics of the municipalities like the altitude, the level of urbanization, coastal areas. From the last census other data were taken at municipal level like the number of families, the number of people employed in different sectors, the number of residential buildings, the number of utilized buildings and the number of active enterprises.
First, to understand data and to have a brief overview of the characteristics of the dependent variable some descriptive statistics were necessary. The dependent variable is the percentage of substituted smart meters which is given by the ratio between the second-generation meters already installed and the total number of meters present in the municipality expressed in percentage. For the analysis only the municipalities whose DSO's is e-distribuzione are considered. From descriptive statistics, it emerged that the municipalities taken into account are 7,428 and the average level of substitution is 73% so aligned with the regional level of substitution. The standard deviation isn't so high in fact it's less than half the average, which means that the level of substitution does not differ much from the average. The descriptive statistics are represented in Table 1:

Table 1 - Dependent variable descriptive statistic

% SUBSTITUTION				
	Percentiles	**Smallest**		
1%	6.23	0		
5%	12.03	0		
10%	15.2	0	**Obs**	7,428
25%	72.415	0	**Sum of wgt.**	7,428
50%	86.495		**Mean**	73.297
		Largest	**Std. dev.**	28.552
75%	91.505	98.59		
90%	94.18	98.67	**Variance**	815.238
95%	95.33	99.02	**Skewness**	-1.417
99%	96.84	99.35	**Kurtosis**	3.378

Source: Author's elaboration

The regressors chosen to explain the differences in the deployment, regard the socio-economic and geographical characteristics of the municipalities. The independent variables taken into considerations were rearranged to make them more meaningful for the analysis purposes. The list of the independent variables utilized for the analysis are described in Table 2.

Table 2 - Description of model variables

LABEL	DESCRIPTION	NOTES
pop	Population of each municipality rescaled by 1000	Average of 2021-2020-2019
sup	Surface of the municipality	Average of 2021-2020-2019
edres	Number of residential buildings (2011)	
alt	Altitude of the municipality (2011)	

rural	1= big cities or highly populated areas; 2= small towns and suburbs; 3= rural areas or scarcely populated areas.	It captures the level of rurality of each municipality (2018)
zocost	1= Coastal areas, municipalities located on the coast or with at least 50 % of the area at a distance from the sea of less than 10 km; 0=Non coastal areas.	Identify if the municipality is in a coastal zone or not
micro.i	Share of micro enterprises (2011)	(Number of Microenterprises/total number of enterprises) *100
unifam	Share of families with only 1 member (2011)	(Number of families with only one member/Total number of families) *100
abocc	Share of occupied dwellings (2019)	(Number of occupied dwellings/Total number of dwellings) *100
occagr	Share of employed in the agricultural sector (2011)	(Number of employed in the agricultural sector/total number of employed) *100
occind	Share of employed in the industrial sector (2011)	(Number of employed in the industrial sector/total number of employed) *100
occter	Share of employed in the tertiary sector (2011)	(Number of employed in the tertiary sector/total number of employed) *100
provdu	Provinces of the Italian territory	

Source: Author's elaboration

After some descriptive statistics to better understand the variables of the model, the linear regression was performed. The linear regression will be estimated with the OLS method, the significant p-values will be those lower or equal to 0.05 marked with "**" and "***" if p-value<0.01. The specific value of the provincial variable is not depicted in the table below because it takes too many values, the provinces involved in the analysis are 104. The reference category for the provincial dummy variable is Ascoli Piceno because, as it has been said before, it's the province with the lowest substitution level (52%) this percentage expresses the average share of substitution of all the municipalities belonging to the province. The result of the regression analysis can be seen in Table 3.

Table 3 - OLS model

Linear regression	
Number of obs	7,322
F (108, 7213)	31.95
Prob > F	0.0000
R-squared	0.2612
Root MSE	24.508

		Robust				
sost	Coefficient	std. err.	t	P>|t|	[95% conf. interval]	
sup	0.020***	0.007	2.830	0.005	0.006	0.034
rural	-3.085***	0.748	-4.120	0.000	-4.551	-1.618

micro.i	0.093**	0.046	2.010	0.044	0.002	0.184
unifam	-0.497***	0.047	-10.630	0.000	-0.589	-0.405
occter	0.328***	0.039	8.470	0.000	0.252	0.404
provdu	Yes					
_cons	67.665***	6.596	10.26	0	54.734	80.596

Source: Author's elaboration

The regressors are jointly statistically significant, in fact the overall F- statistic has a p-value of 0.000. The R-squared tells us that the model is pretty good considering that 26.12% of the variation of the dependent variable is explained by the regressors present in the model.

The estimated effect of sup suggests that the surface has a positive effect on the share of substitution, the surface identifies the largest municipalities which are more populated and present the largest number of buildings. It's reasonable to affirm that e-distribuzione prioritized the largest municipalities in the installation pattern also because they require more time to get to a total coverage than small municipalities. Looking at the effect of rural it's possible to affirm that there is a negative relationship with the dependent variable, this means that if a municipality is classified as rural, the share of substitution will be lower. This is coherent with what was stated above, rural areas in general are small municipalities, less populated and with a lower consumption of electricity.

The presence of microenterprises (micro.i) influences positively the share of substitution of smart meters, they are synonymous of active municipalities from an economic point of view and so with a high electricity consumption.

Families with only one member (unifam) influence negatively the level of installation, the coefficient suggests that this regressor is particularly significant in the model. This variable is a proxy of the electricity consumption in the families: it's realistic to affirm that families with only one member utilizes less electricity than larger families.

The regressor could also suggest the age composition of the population in the municipalities, in Italy there is the phenomenon of the ageing population and so a large proportion of single-member households could be due to elderly people living alone that do not consume so much electricity.

The estimated coefficient of occter has a positive effect on the share of substitution of smart meters, as the number of employees in the tertiary sector grows, the percentage of substitution of smart meters increases keeping all the other variables constant.

The provincial variable has been fundamental to improve the model, in fact thanks to this dummy the overall significance of the model increased and it's also possible to gain additional information, like the fact that belonging to certain provinces improves the possibility of having a high installation rate. Ascoli Piceno in the installation ranking results as the worst province, however as it's possible to see from detailed coefficients obtained from the multiple regression analysis, the province that performed worse is Livorno. The province that achieved the best result with respect to Ascoli Piceno is Belluno. The subcontracted enterprises of e-distribuzione have been more reactive in some provinces than in others.

The provincial variable gives useful insight on what are the most virtuous area for smart meters substitution. Smart meters implementation is a technological diffusive process that from a logistic point of view is not casual, in fact it is demonstrated by the research that the provincial factor has an important impact on the deployment. From the provdu variable it is possible to affirm that certain provinces are performing better than others, but these are equally distributed in the national territory. The provincial variable is useful also because some interesting information are given in combination with the dependent variable. With a transformation of the dependent variable in a dummy one, where 0 stands for an installation rate lower or equal to 50% and 1 if the installation rate is higher, it's possible to obtain a more precise picture of the installation situation in the Italian territory. Data shows that some provinces have no municipalities with a substitution rate lower than 50%, the province in question are reported below in Table 4, they represent 24% of the provinces covered by e-distribuzione.

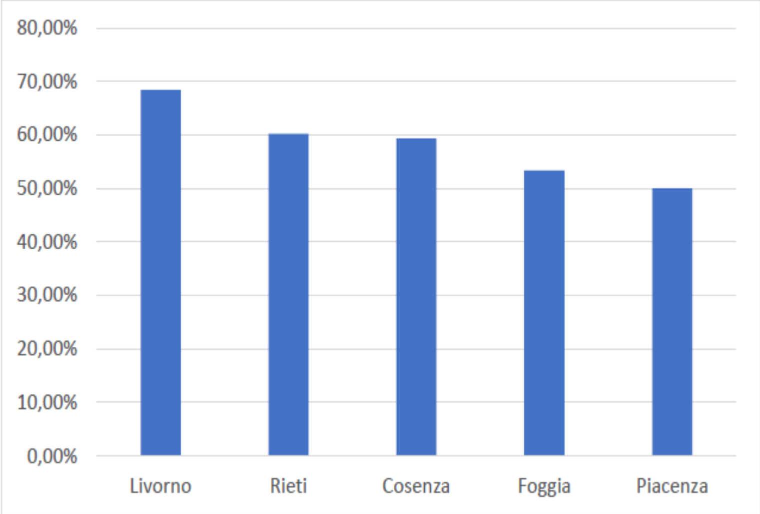
Table 4 - Provinces with no municipalities with an installation rate lower than 50%

PROVINCE	NUMBER OF MUNICIPALITIES
Agrigento	42
Arezzo	36
Bologna	53
Brindisi	20
Cagliari	17
Caltanissetta	22
Catanzaro	80
Cremona	111
Crotone	27
Enna	20
Ferrara	21
Frosinone	89
Gorizia	24
La Spezia	32
Latina	32
Matera	31
Oristano	87
Pescara	46
Potenza	100
Prato	7
Ragusa	12
Siracusa	21
Taranto	29
Teramo	47
Trieste	5

Source: Author's elaboration

Provinces with more than 50% of municipalities with an installation rate lower than 50% are depicted in Figure 8. The province with the highest percentage of municipalities with a substitution rate lower than 50% is Livorno, which is also the province with the lowest number of municipalities among the ones considered in the figure below.

Figure 8 - Percentage of municipalities with a substitution rate lower than 50%



Source: Author's elaboration

As can be seen from Figure 8, the provinces considered are located in North, Centre and South Italy so there aren't so many discrepancies among the three main areas of the national territory. The result is coherent with what has been said so far considering that Livorno is the province that has performed worse in the regression analysis containing all the observations.

From all these analyses performed it's possible to affirm that at least in part, the level of replacement of municipalities is affected by their geographical and socio-economic characteristics.

Larger municipalities with characteristics of urbanisation which are more populated are favoured in substitution decisions. The composition of the family is an important element that influences the decisions of installations, as the regressor unifam turns out to be significant. From the analysis of the provincial variable, it's possible to confirm what e-distribuzione has stated in the plan considering that from a geographical point of view there aren't so many discrepancies among the North, Centre and South area.

From the analysis another important element which emerges is the role of the rurality in smart meters deployment: municipalities with a high substitution share are the ones characterized by urbanization elements. Italy is characterised by 62% of municipalities classified as rural by EUROSTAT, nevertheless the rurality index seems to have a negative effect on substitution share. Although Italy is a pioneer in the installation of smart meters, rural areas are disadvantaged here like in the other States of the European Union. This is consistent with the opinion of the European Economic and Social Committee on "The energy and digital transition in rural areas" (J. Comer et al., 2022).

The report also highlights the critical issues faced by rural areas. Many rural areas are physically isolated with low population density. It can be said that rural areas are more vulnerable because of low incomes and a population that is ageing.

The energy transition is made up of many elements, one of which is the installation of smart meters. As stated also before, energy transition does not depend only by changes in the sources used to produce electricity but also by a change in consumption behaviour. Knowledge of the level of consumption is crucial in order to be able to reduce it, and certainly the population category composed by old people living alone in rural and isolated areas is at a disadvantage, like demonstrated by the results of regression analysis.

Smart meters alone cannot bring a change in electricity consumption. Information and awareness-raising campaigns on how to use the tool and what are the functionalities are however necessary to take a step towards a more sustainable future and a full use of the instrument.

4. Conclusions

Previous research was conducted in this field to understand the drivers that lead the installation path across different countries. Smart meters diffusion across European countries and beyond is a good example of how the same technology can spread at different speeds when deployed in different but similar countries – such as the EU Member States. Differences are obviously influenced by the regulatory approach and the economic policies adopted in each country: in fact, we need to remember that, despite a certain liberalization, the energy and electricity sectors continue to be substantially regulated. Moreover, as in every technological diffusion process, also market factors may also play a conditioning role, because regulated operators also face financial and economic constraints.

However, the market-driven factors are better appreciated once taken as given the policy-sphere: and this naturally pushes the empirical analysis towards a regional or municipal level focus, where regulation does not play a distinct role.

The article focuses on the Italian case, by exploiting a very granular dataset (municipality level). It refers to installations measured in 2022 and referring to n. 7,428 municipalities. The regression analysis carried out showed that the presence of certain characteristics discourages second-generation smart meters substitution. In detail, the research points out that rural municipalities register a lower rate of substitution, like the municipalities with a high share of families with only one member.

All in all, the considered independent variables are able to explain a significant part of the substitution share across municipalities, and the smart meters roll-out is a proper technological diffusion process subject to market influence: therefore, it's not a casual process.

To conclude, given the key role of this innovation to lead the electricity sector towards a more sustainable future, the analysis of the diffusion of smart meters in Italy and its drivers has allowed to understand which are the exogenous and market factors that have influenced in the recent past (and are likely to influence in the near future) the decisions of installation and the level of coverage reached by technology in the national territory.

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