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Abstract

It is generally accepted that institutions are important for economic development. However, whether the performance of regulated utilities within a country is affected by the quality of institutions is yet to be investigated thoroughly. We analyse how the quality of regional institutions impact performance of Italian electricity distribution utilities. We use a stochastic frontier analysis approach to estimate cost functions and examine the performance of 107 electricity distribution utilities from 2011 to 2015. This unique dataset was constructed with the help of the Italian Regulator for Energy, Networks, and Environment. In addition, we use a recent dataset on regional institutional quality in Italy. We present evidence that utilities in regions with better responsiveness towards citizens, control of corruption, and rule of law, tend to be more cost efficient. The results suggest that national regulators should take regional institutional diversity into account in incentive regulation and efficiency benchmarking of utilities.

Keywords: institutional quality; stochastic frontier analysis; electricity distribution in Italy; cost efficiency; inefficiency determinants.

JEL classification: D22, L51, L94, O43.

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1. Introduction

Over the past three decades and in particular since the seminal work by North (1990), impact of institutions on economic development has been investigated and confirmed by empirical studies. More recently, the same trend is observed for the impact of macro-level factors on firms' total factor productivity (Lasagni et al., 2015). However, whether the performance of regulated network utilities can also be affected by the quality of institutions has been explored to a lesser degree. Recently, a few studies have examined this subject (Jamasb et al., 2018; Borghi et al., 2016; Nyathikala et al., 2018). These studies highlight how economic and technical efficiency by utilities can be hindered due to poor quality of institutions.

However, there is a need for more research as some questions remain. For instance, whether the variations of utilities' efficiency in developed economies, despite their relative technical advantage, is influenced by the quality of sub-national institutions. Can some of the performance differences of utilities in a country be traced to differences in regional institutional characteristics as well as the geographical and economic differences? Do national energy regulators need to consider the differences in the quality of regional institutions in incentive regulation and efficiency benchmarking of network utilities? In this paper we aim to provide a better insight on these issues by analysing the performance of the Italian electricity distribution utilities.

In the 1990s, electricity sector reforms began in many countries around the world aiming at promoting privatisation and liberalisation in network industries (Armstrong et al., 1994). Due to technical and economic characteristics, the distribution networks of the electricity industry had traditionally been regarded as natural monopolies. Since the distribution network can be subject to market failure, it is more efficient to regulate this segment of the electricity system rather than relying on market-based models (Joskow, 2014; Jamasb and Pollitt, 2007; Giannakis et al., 2005; Newbery, 2000). Therefore, as part of the reforms, independent sector regulators were established to ensure fair treatment of consumers as well as efficiency improvements (Jamasb and Pollitt, 2007). In this context, incentive-based mechanisms and efficiency benchmarking methods have been widely used by many sector regulators to evaluate the performance of distribution network utilities.

Despite almost three decades of electricity sector reforms, the performance of utilities across different regions of countries around the world seems to be diverse and non-homogenous.[1] This lack of homogeneity can be linked to geographical differences (Cambini et al., 2016), diverse weather conditions (Llorca et al., 2016) as well as economic development (Jamasb et al., 2018). However, not only technical, economic, and geographical measures may affect firms' efficiency. Regional and local institutional settings, within which regulated firms operate, might also influence firms' performance. Hence, it is worthy to explore whether regional institutional measures also impact performance of network utilities across a country.

Italy was among the first countries to implement electricity sector reform in 1990s. The Italian Regulatory Authority for Energy, Networks and the Environment (*Autorità di Regolazione per Energia, Reti e Ambiente*, ARERA) was established in 1995 to promote competition in electricity generation as well as ensuring efficiency and quality of services provided by the transmission and distribution utilities. To this aim, ARERA has applied incentive-based mechanisms since 2002 to encourage utilities to improve their productive efficiency and improve service quality. After nearly two decades of reforms, although the Italian power system is considered as one of the most developed in the world, the electricity distribution sector exhibits persistent inefficiency and service quality issues across the regions of the country. Meanwhile, regional differences between northern and southern regions raise the question whether the dissimilar levels of economic development and differences in quality of institutions, also affect the performance of electricity distribution utilities.

In this paper we address this question by examining the impact of regional-level institutional quality on the efficiency of the Italian electricity distribution utilities from 2011 to 2015. We use a novel and high-quality dataset that has been constructed with the help of ARERA, allowing us to use regulatory accounting data on network distribution segment, i.e., the regulated segments, excluding the potentially competitive activities. We complement this data with information on quality of institutions at regional-level from Nifo and Vecchione (2014). Due to the historical socioeconomic gap between northern and southern areas, Italy is an ideal case study to explore the potential link between economic and institutional endowments, and performance of network utilities. We use a set of Stochastic Frontier Analysis (SFA) models to

[1] For instance, this is the case for the Indian electricity distribution utilities (Jamasb et al., 2018). In Italy, there is a wide gap between performance of utilities located in northern and southern regions (Cambini et al., 2014).

estimate cost functions to examine the impact of regional-level economic and institutional factors on cost efficiency of the electricity distribution utilities in the country.

The paper is organised as follows. Section 2 provides an overview of the literature on the impact of quality of institutions on performance of firms, in particular electric utilities. In Section 3 we present a brief institutional background of the Italian electricity industry. Section 4 discusses the estimation methodology and the models we use in this paper. In Section 5 we present the dataset and how the variables are structured. We present and discuss the estimation results in Section 6. Finally, in Section 7 conclusions and policy implications are provided.

2. Literature Review

The role of institutions in economic development was first acknowledged by North (1990). In the past three decades, a large number of studies have examined the impact of institutional quality on economic development. Using regional and cross-country data, several studies provide empirical evidence that a higher quality of institutions translates into higher rates of economic growth (Easterley and Levine, 2003; Acemoglu and Robinson, 2008; Chanda and Dalgaard, 2008; Grigorian and Martinez, 2002). Hall and Jones (1999) define institutions and government policies as the social infrastructure driving differences between countries in terms of capital accumulation and productivity. Acemoglu et al. (2001; 2002), focuses on countries which experienced European colonialism and finds a strong relationship between good institutions and higher income per capita.

Kim and Law (2012) examine the relationship between institutions and local-urban development in the Americas and conclude that spatial economic development is affected by institutional factors such as political centralisation. Gyimah-Brempong and de Camacho (2006) use a sample of 61 countries with diverse levels of economic development to examine the regional differences in terms of the impact of corruption, as an institutional measure, on economic development. They find strong evidence that regional differences in growth and income distribution can be traced back to the level of corruption in regions and countries.

Impact of institutions on firm-level economic activity on the other hand, has been of interest for researchers in recent years. How institutions impact investment patterns in human and physical capitals and consequently on firms' productivity has been investigated by several studies (Mankiw et al., 1992; Ketterer and Rodriguez-Pose, 2012; Rodrik et al., 2004). Eicher et al. (2006) suggest that institutions affect factor productivity and better institutions improve output through physical capital. Dollar et al. (2005) consider investment environment as a proxy for institutions and highlight the differences between the investment climate across countries and their regions. They confirm that better investment climate induces higher firm productivity. Lensink and Meesters (2014) using cross-country data show that well-developed institutions result in more efficient operation of commercial institutions.

The political economy literature has also developed a vast array of variables capturing formal institutional and political arrangements and their impact on different economic variables (see, e.g., Acemoglu, 2005; Persson and Tabellini, 1999). Part of this literature is focused on the microeconomic effects of political institutions and social capital on regulated firm performance. For instance, electoral cycle influences the price setting for specific regulated services (Moita and Pavia, 2013). Political institutions are also found to affect regulated firms' investment decisions (Henisz and Zelner, 2001; Cambini and Rondi, 2017). The impact of political institutions may depend on country characteristics. In developing countries with higher checks and balances, governments find it easier to commit credibly to policies, and this positively affects private investment (Stasavage, 2002). Social capital is associated also with more benign politics, greater political stability, and accountability (Knack and Keefer, 1997). Corruption also impacts performance dimensions such as access, affordability and quality in telecommunications, electricity, and water sectors in developing countries (Estache et al., 2009). Finally, political institutions also influence the outcomes of regulatory agencies increasing the market-value of state-owned firms when institutions are particularly weak (Bortolotti et al., 2013).

These studies confirm the impact of political institutions on firm performance typically in highly heterogeneous country samples including developing and developed nations, and within developed country sample only. However, and as an added value of our analysis, any of these analyses focus on local institutions, i.e. on the impact of regional political institutions on local firms where the interplay between firm performance and local political variables is more complex. In general, very few papers address such research questions and in particular in regulated network utilities. In particular, the role of institutions, in particular corruption, has been examined in solid waste industry in Italy by Abrate et al. (2015) and D'Amato et al. (2015).

To our knowledge, our paper is among the first to assess the link between political institutions and corruption on firm performance within the regulated electricity network utilities using a wide set of local political and institutional variables.

Electricity transmission and distribution networks, due to their technological characteristics, are appropriate choices to examine if such a relationship exists. Electricity distribution networks are natural monopolies and therefore subjected to economic regulation. They are also rather similar in design. Thus, the sources of inefficiency and unobserved heterogeneity in this sector might be traced back to structural and environmental factors that are out of firms' control, as well as how utilities manage their resources rather than pure technological differences.

Although the literature on determinants of firms' performance in electricity distribution is extensive, empirical evidence on whether institutional quality can be one of the sector's sources of inefficiency is scant. The main drawback is the fact that the electricity sector is facing reform processes around the world and as a consequence, reforms have been widely considered as a proxy for the institutional environment in the literature. Consequently, a large body of research has focused on how regulatory reforms impact performance of utilities (e.g., Pombo and Taborda, 2006; Andres et al., 2008; Stern and Cubbin, 2005). In such studies, the impact of reforms has been considered as the main element within the general impact of institutions. However, institutions can be defined by a varied set of proxies and therefore, taking reforms as the only measure of the country's institutional settings can result in misleading conclusions.

Another gap in the literature is the lack of empirical evidence on the impact of 'local/regional institutions' on performance of electricity utilities located in different regions of a country. This is mainly due to the fact that data on quality of institutions at regional level is not as accessible as country-level data. Consequently, the majority of analysis looks at inter-country differences rather than inter-regional diversity (Bortolotti et al., 2013). Within this framework, it is worth summing up a brief review of the literature on the impact of institutions on the performance of the sector.

Bergara et al. (1998) is one of the first to shed light on this subject. They investigate the impact of political institutions on investments in the electricity industry. Using a cross-nation analysis, they show that a well-defined political institution can enhance electricity generation capacity.

More recently Dramani and Tewari (2014) find similar result for electricity sector performance in Ghana. Balza et al. (2013), examines how reforms affect performance of the electricity sector in 18 Latin American countries. They show that credible sectoral institutions, in particular regulatory quality, play a central role in the industry's performance improvements. On the contrary, Durakoglu (2011), studying the Turkish electricity distribution sector, suggests that regulatory governance itself can be affected by political endowments and therefore good regulatory content does not necessarily translate into a successful reform. This result is in line with what has been suggested by Rodrik (2003) arguing that a sound reform process, which has the potential to encourage productive firms, requires a sound institutional framework.

Nepal and Jamasb (2012; 2013) discuss the same rationale for the electricity sector reforms and suggest that the success of reforms depends not only on micro and macro factors but also on the country's institutional factors as well as reforms in the wider economy. Erdogdu (2013) uses a cross-country analysis and shows that electricity reforms are more effective in countries with higher institutional quality. Dal Bo and Rossi (2007) investigate whether corruption can be considered as an inefficiency determinant for electricity utilities. Using cross-country data from Latin America they find evidence that higher levels of corruption translate into a higher number of inefficient firms. Estache et al. (2009), consider corruption as a proxy of the whole institutional quality and suggest that reforms can only reduce impact of corruption on performance of regulated firms to some extent. They confirm the impact of institutional quality on reforms by showing that with high levels of corruption reforms are not effective.

Borghi et al. (2016) analyse electricity distribution firms in 16 EU countries to explore how the interaction between ownership and quality of government affects firm-level efficiency. They find that where measures of government quality are higher, public firms show higher efficiency scores, while with poor quality of institutions private firms seem to be more productive. Their analysis, however, examines country-level data rather than regional-level data within a single country as we do in our analysis.

Jamasb et al. (2018) study the Indian electricity distribution sector and examine a set of proxies representing quality of institutions to examine whether state-level economic factors and institutional quality affect firms' performance. They find that state-level economic and institutional characteristics have an impact on efficiency of firms. However, the study uses a set of metrics that can be considered as relatively distant proxies for quality of institutions. They use an index of Human Development and political rules (e.g., the number of Times the Chief Minister Headed the Coalition Government or the President imposes ad hoc rules[3]) which are not a direct measure of the overall institutions in a region or state. In our paper, instead, we use measures of regional institutional quality that are constructed based on World Governance Indicators directly related to the law system, the degree of corruption, and political stability, and that therefore directly measure the quality of regional institutions within a country.

3. The Italian electricity sector and institutional context

Italy was among the first countries to start the reform process of the electricity sector in the 1990s. The Italian national regulator, currently named Regulatory Authority for Energy, Networks and the Environment (ARERA) was established in 1995 with the aim to promote competition in the electricity generation sector and ensure efficiency and higher quality of services provided by transmission and distribution utilities. The primary objective of the reforms in Italy was to liberalise the electricity market and to move from a monopolistic structure towards an open economic sector where competition was possible. Prior to the reforms, *Enel*, the largest electricity utility in Italy, was owned by the Ministry of Economy and had monopoly of the entire electricity sector. In 1999, following the legislative decree n. 79/1999, known as the ”Bersani Decree”, *Enel* was required to unbundle its generation, transmission, and distribution activities and to share its networks with a few competitors including *Endesa Italia*, *Edipower* and *Tirreno Power*. Until 2002, under the unbundling rule, monopolistic (i.e., distribution and transmission) and competitive (i.e., electricity generation and trading) corporate activities were separated. The primary objective of the reforms was achieved in 2007 when, following the ongoing electricity sector privatisation and liberalisation actions, the sector was declared as fully open to private customers.

ARERA has applied incentive-based mechanisms since 2002 to encourage utilities to improve their productive efficiency and quality of service. However, despite nearly two decades of reforms and regulatory efforts to enhance efficiency as well as quality of service standards in Italy, there exist persistent inefficiency and service quality issues across the regions of the

[3] In the Republic of India, “Article 356 provides for the imposition of President’s Rule in States to combat a situation ‘in which the Government of the State cannot be carried on in accordance with the provisions of the constitution’” (Arora, 1990, p.1).

country. Utilities in northern parts of Italy seem to use their resources more efficiently relative to those in southern and central areas and consequently, performance metrics of utilities located in different regions are widely dispersed (Cambini et al., 2014; Capece et al., 2013). The sector also suffers from high number of interruptions, in particular in the southern part of the country (ARERA, 2017).

These persistent issues suggest the presence of exogenous factors which can stall efficiency and quality improvements. In Italy differences in environmental characteristics including weather conditions, area covered by forests, or coastal locations are among the factors leading to diverse efficiency scores across the country (Cambini et al., 2016). However, the differences between northern and southern regions raise the question whether dissimilar economic development levels and differences in quality of institutions, can affect performance of electricity distribution utilities. Identifying roots of development difference between northern and southern regions has been a macro-level research topic for a long time. The difference in performance of firms in north and south has also attracted some attention from researchers. Lasagni et al. (2015) use the regional Institutional Quality Index (IQI), constructed by Nifo and Vecchione (2014), to examine how regional quality of institutions impact total factor productivity of the Italian manufacturing firms. They find that better business environment and institutional context improve firm-level productivity. Nonetheless, impact of institutions on the regulated Italian distribution utilities has not been investigated.

Few studies have investigated the efficiency of the energy sector in Italy. Capece et al. (2013) analyse the Italian energy sector using energy utilities' financial information and conclude that performances of utilities in northern and southern areas of the country are widely unequal. More specifically, previous research on the Italian electricity distribution (Fumagalli and Lo Schiavo, 2009; Cambini et al., 2014; 2016) mostly focuses on the evaluation of output-based incentive mechanisms with respect to quality of service and not necessarily on the efficiency of the sector. Moreover, two of these studies, Cambini et al. (2014; 2016), only use the data available on *Enel* activities, and not the remaining Italian utilities, which is the data utilised in this paper.

This paper aims to fill the gap in the literature on how quality of local institutions impact performance of utilities across a country while it gives an insight into performance of Italian electricity distribution utilities. The novelty of this work is two-folded. First, we use take a novel and unique regulatory accounting dataset on the Italian electricity distribution utilities made available to the authors by ARERA. Second, we use regional institutional quality measures, constructed based on World Governance Indicators, to examine impact of quality of local institutions on performance of regulated network utilities.

4. Methodology

When analysing performance of utilities, it is common to estimate either variable or total cost functions (Filippini and Wetzel, 2014). In addition, in the electricity sector, frontier approaches are widely used for benchmarking objectives as well as estimating technical, allocative, and cost efficiency.[4] Among the parametric and nonparametric frontier approaches Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are respectively the two most utilised to analyse the efficiency of the transmission and distribution utilities. In practice, the choice between parametric and nonparametric approaches depends on the research or the regulatory objectives (see Coelli et al., 2005).

In this paper we aim to identify macro-level inefficiency determinants of the electricity distribution sector. We estimate a total cost function using an SFA approach. Considering that firms are cost-minimising entities, a total cost function can be written as:

$$TC = f(y, p, x, \beta) \tag{1}$$

where TC is firms' total costs, y represents outputs including energy delivered, number of customers, and average duration of interruptions per customer, p is the vector of input prices including capital and labour prices, x stands for the control variables, and β represents the parameters to be estimated. The total cost function must be non-decreasing in outputs and input prices, and linearly homogeneous with respect to input prices.

We use a heteroscedastic SFA model to estimate a total cost function using an unbalanced panel dataset.[5] This approach allows us to estimate the cost efficiency of the utilities, while taking into account the impact of quality of institutions as inefficiency determinants. The original form of stochastic frontier models was first introduced simultaneously by Aigner et al. (1977) (ALS

[4] See Farsi and Filippini (2009) for a review of studies on cost function estimation and frontier approaches.
[5] SFA is considered to be easily applied to panel datasets (Farsi and Filippini, 2009).

henceforth) and Meeusen and van den Broeck (1977). The random term in these models includes two components incorporating statistical noise and inefficiency. Pitt and Lee (1981) and Schmidt and Sickles (1984) applied SFA models to panel data to interpret random and fixed effects as inefficiency rather than unobserved heterogeneity (Farsi et al., 2005). Orea and Jamasb (2017) and Orea et al. (2018) use a latent class and spatial approach to unobserved heterogeneity and omitted variables respectively in Norwegian electricity distribution utilities. These models, however, consider the inefficiency term to be time-invariant meaning that the inefficiency level of each firm remains unchanged over time, which is considered to be an unrealistic assumption (Kumbhakar et al., 2015). Later, Kumbhakar (1990) and Battese and Coelli (1992) proposed models which allow including time-varying inefficiency terms.

The general form of a stochastic cost frontier can be presented as follows:

$$\ln TC_{it} = \ln f(y_{it}, p_{it}, x_{it}, \beta) + v_{it} + u_{it} \qquad (2)$$

where i denotes the firm and t stands for time, v is the statistical noise term, which follows a normal distribution and u is an inefficiency term that captures firms' cost inefficiency and can follow a range of distributions, such as the half-normal, the truncated normal or the exponential.

It should be noted that the original models by Aigner et al. (1977) and Meeusen and van den Broeck (1977) do not allow to analyse the presence of factors that may influence firms' efficiency. Diverse models have been developed in the SFA literature to address this issue (for a summary see Alvarez et al., 2006; Lai and Huang, 2010; or Llorca et al., 2016). Some of these models fulfil the so-called *scaling property*, which implies that the inefficiency term can be decomposed in the following way:

$$u_{it}(z_{it}, \delta) = h(z_{it}, \delta) \cdot u_{it}^{*} \qquad (3)$$

where u_{it}^{*} is a random variable that captures firm's base efficiency level and $h(z_{it}, \delta)$, which represents the scaling function. In these models, the efficiency level of firms depends on u_{it}^{*} and its scale changes by a function of z_{it}, i.e., the environmental variables. This is in fact the specific feature of the scaling property: the scaling function only changes the scale of the inefficiency term and not its shape which is determined by the basic random variable (Alvarez et al., 2006). Therefore, as emphasised by Llorca et al. (2016), the scaling function is responsible for adjusting the level of inefficiency upwards or downwards under the influence of inefficiency determinants.

Among the models which fulfil the scaling property, we follow the model of Reifschneider and Stevenson (1991), Caudill and Ford (1993), and Caudill et al. (1995).[6] In this model (RSCFG henceforth) the inefficiency term, u_{it}, follows a half-normal function while the scaling function, $h(z_{it}, \delta)$, takes an exponential functional form. Therefore, the inefficiency term can be rewritten as:

$$u_{it}(z_{it}, \delta) = \exp(z_{it}'\delta) \cdot u_{it}^{*} \tag{4}$$

Consequently, the final total cost function to be estimated will be as follows:

$$\ln TC_{it} = \ln f(y_{it}, p_{it}, x_{it}, \beta) + v_{it} + \exp(z_{it}'\delta) \cdot u_{it}^{*} \tag{5}$$

As for the specification of the cost frontier, we estimate both the Cobb-Douglas and (a more flexible) translogarithmic (translog) functional forms. The flexibility feature of the translog corresponds to the fact that the signs of the first and second-order derivatives are not set ex-ante (Ramos-Real, 2005). After comparing the two functional forms taking into account the goodness of fit, the translog model is selected to include the inefficiency determinants. Further details on the estimated functional forms are in the next section.

5. Data and Model Specification

[6] It should be noted that the inefficiency determinants can be introduced in the SFA models through the pre-truncation mean (see, Battese and Coelli, 1995) and/or the pre-truncation variance (see, Reifschneider and Stevenson, 1991; or Caudill and Ford, 1993) of the inefficiency term. Inclusion of these inefficiency determinants and the final choice of model depends strongly on the characteristics of the dataset. In particular, we also estimated the panel data model of Battese and Coelli (1995), as well as the model of Battese and Coelli (1992). However, we experienced a lack of convergence problem when trying to estimate these models.

We use a unique dataset of 107 utilities active in the Italian electricity distribution sector, from 2011 to 2015, in 15 Italian regions,[7] based in 3 geographic areas.[8] The firm-level data[9] comprises regulatory accounting data on network distribution segment only (i.e., they do not include potentially competitive activities such as commercialisation[10]), as well as data on physical aspects of the electricity distribution networks owned by the utilities (e.g., energy delivered, length of lines, number of customers, number of transformers). These data were collected and exclusively made available to the authors by ARERA.[11] The data on quality of service (average frequency and average duration of interruptions per customer) is available from the ARERA online database.

After data cleaning, removing missing values, and dropping outliers, we obtained an unbalanced panel with a total number of 237 observations. One outlier in the final analysis is *Enel* (*E-Distribuzione*) and its corresponding regulatory and physical data. *Enel* owns about 86% of the Italian electricity distribution network and operates in almost all Italian regions, with 115 operating districts in total (Cambini et al., 2014). However, the dataset in hand contained only information on *Enel* activities as one unit, which converts it in an outlier due to its large operation domain compared to other utilities in the sample. Therefore, we perform our analysis by excluding the country-wide *Enel.* The data on economic development measures are at regional-level and extracted from ISTAT[12] and Eurostat[13] online databases. In particular, we have included regional Gross Value Added to account for regional-level economic development characteristics that can potentially affect firm-level efficiency.

In order to assess the impact of institutional quality on performance of the electricity distribution utilities in Italy, we use a database on institutional quality measures constructed by

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7 The regions are: Piemonte, Lombardia, Liguria, Veneto, Trentino Alto Adige, Valle d'Aosta, Abruzzo, Marche, Emilia Romagna, Friuli Venezia Giulia, Sicilia, Sardegna, Puglia, Lazio and Umbria.

8 Since 2000, for regulatory purposes, ARERA divides the Italian territory into three areas or *circoscrizioni*: north, centre, and south (Cambini et al., 2014). We use the same geographical classification to reflect the locational and geographical diversity.

9 A detailed description of variables extracted from the dataset collected by ARERA as well as variables extracted from other resources is presented in Appendix A.

10 Following Directive 96/92/CE of 1996 and under the unbundling rule, competitive and monopolistic corporate activities are separated in the electricity sector across the European Union.

11 Under the accounting separation obligations (CAS, *Conti Annuali Separati*), ARERA requires distribution utilities to collect and submit their annual regulatory accounting statements to the online repository of the authority.

12 *Istituto Nazionale di Statistica*, ISTAT, is the Italian national institute of statistics which collects and produces social, economic, and environmental statistical information in Italy. It is accessible at: www.istat.it.

13 Eurostat database is accessible at: https://ec.europa.eu/eurostat/data/database.

Nifo and Vecchione (2014).[14] Following the framework proposed by Kaufmann et al. (2011) to construct the World Governance Indicators (*WGIs*), they developed the Institutional Quality Index (*IQI*) for each Italian region. In particular, they used 24 elementary indexes[15] to construct 5 key dimensions of quality of governance: voice and accountability, government effectiveness, rule of law, regulatory quality[16] and corruption. They then use a weighted average of these 5 categories to construct *IQI* which captures the overall quality of institutions in each Italian region. The regional scale of these indexes allows us to examine whether the differences in performance of utilities located in various regions of a country can be explained by the differences in quality of regional institutions.

Table 1 reports descriptive statistics of the variables utilised in this study (excluding *Enel* figures).[17] As expected, due to the unbalanced nature of our sample, the range (the difference between minimum and maximum values) of output and input variables is quite large. This, once again, indicates the diverse operational characteristics of the utilities ranging from small (with 10 consumers) to large (over 1.5 million consumers) utilities. The same is observed for price of labour. Due to technical characteristics of distribution networks, utilities can outsource most of their operational activities. Therefore, the wide gap between minimum and maximum labour prices can be linked to operational or outsourcing strategies of the firms.

Table 1. Descriptive Statistics

Variable	Unit	Min.	Max.	Mean	Std. Dev.
Totex	Euros (2010)	5,656	315,185,156	11,209,170	39,082,340
ENED	MWh	673	11,334,422	393,498	1,573,321
CUST	No of Customers	10	1,626,019	51,661	206,264
SAIDI	Minutes	0.01	8,067	125.84	429.86
LPR	Euros (2010)	200	265,430	52,935	28,226

[14] The database is available at: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
[15] See Nifo and Vecchione (2014) for a detailed description of the indexes.
[16] Nifo and Vecchione (2014) define regulatory quality as "Regulatory quality concerns the degree of openness of the economy, indicators of business environment, business density and the rate of firms mortality". This index is defined as "Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" by Kaufmann et al. (2011). We realize that "regulatory quality" can derive a different meaning for regulated industries however in order to remain compatible with the institutional definition of the index as well as compatibility with the main sources of the governance indicators (*WGIs* and *IQI*) we kept the name "regulatory quality" also in our analysis.
[17] In Appendix B you can find Table B.1. which presents descriptive statistics of variables with respect to the three areas in which utilities are located: north, centre, and south and Table B.2. which demonstrates the level of correlation between different variables.

KPR	Euros (2010)	0.01	21,466	1,871	1,811
North	Dummy	0	1	0.87	0.33
Centre	Dummy	0	1	0.08	0.27
South	Dummy	0	1	0.05	0.21
Mount	Dummy	0	1	0.78	0.41
Corp	Dummy	0	1	0.78	0.41
Multiregion	Dummy	0	1	0.019	0.14
GVA	Euros (2010)	14,295	33,822	30,273	4,854
Voice	Index	23	65	48.62	7.44
RoL	Index	30	81.70	69.84	12.17
Gov_Eff	Index	17.40	61.40	46.50	7.46
Corru_Ctrl	Index	61.40	97.30	90.43	5.86
RQ	Index	21.50	72.2	63.52	9.89

We use all five dimensions of the governance quality as institutional inefficiency determinants of the electricity distribution sector: control of corruption, voice and accountability, rule of law, government effectiveness, and regulatory quality. It should be noted that only minor changes in governance indicators would happen over year-to-year periods. In fact, the producers of *WGIs* suggest that users of these indicators "should in most cases not focus on short-run year-to-year changes but rather in trends over longer periods".[18] Consequently, we used average values of the regional quality indexes and these variables are in fact time-invariant in our sample.

Following the discussion in Section 4, the econometric specification of our model that takes the translog functional form can be presented as follows:

$$\ln\left(\frac{Totex_{it}}{LPR_{it}}\right) = \alpha + \sum_{n=1}^{3}\beta_n \ln y_{nit} + \beta_K \ln\left(\frac{KPR_{it}}{LPR_{it}}\right) + \sum_{n=1}^{3}\sum_{m=1}^{3}\beta_{nm} \ln y_{nit} \ln y_{mit} +$$
$$\frac{1}{2}\beta_{KK}\left[\ln\left(\frac{KPR_{it}}{LPR_{it}}\right)\right]^2 + \sum_{n=1}^{3}\beta_{nK} \ln y_{nit} \ln\left(\frac{KPR_{it}}{LPR_{it}}\right) + \beta_{Centre}Centre_i + \beta_{South}South_i +$$

[18] See the World Governance Indicators project by the World Bank at https://info.worldbank.org/governance/wgi/.

$$\beta_{Corp}Corp_i + \beta_{Mount}Mount_i + \beta_{Multiregion}Multiregion_i + \beta_T T + \nu_{it} + \exp(\textstyle\sum_{r=1}^{8} \delta_r z_{rit}) u_{it}^* \quad (6)$$

where α is the intercept, y represents the outputs and z corresponds to the efficiency determinants included in our analysis.

As mentioned, the dependent variable is total network cost of distribution utilities ($Totex$).[19] For each distributor, $Totex$ is constructed by summing up operational expenditure (Opex) and capital expenditure (Capex). Opex consists of employee cost, operations and maintenance cost, materials cost, administrative and general expenditure and other costs. Capex is made up of total depreciation and interest. As explanatory variables, we consider three outputs, two input prices, and a set of variables controlling for the area and geographic characteristics as well as the legal status of the utilities. Since the main operation of the distribution utilities is to deliver energy to the final consumers, we select these two variables as outputs. Moreover, amount of energy delivered, and number of customers are among the most used output variables when estimating efficiency of electricity distribution utilities (Jamasb and Pollitt, 2001).

As for the third output, we use the average outage duration for each customer served, in minutes (*SAIDI*). This variable should be interpreted as a bad output in the electricity distribution activity defined in our model. Selection of this variable is compatible with the output-based regulation of the Italian regulatory authority which has been established since 2004. According to this regulatory scheme, a quality of service measure is set, *ex-ante*, by the regulator and utilities are either rewarded or penalised depending on whether they have reached the required threshold or not. In this sense, *SAIDI* is linked with the level of effort taken by the utility to mitigate interruptions and improve its service quality.

Labour price (*LPR*) and capital price (*KPR*)[20] are the two input prices and both are firm-specific. In order to impose homogeneity of degree one in prices, both *Totex* and capital price values are

[19] All the monetary values are deflated to the 2010 values using the Consumer Price Index (*CPI*).

[20] Capital Price calculation for the electricity distribution utilities needs detailed data which is not publicly disclosed by firms and therefore, usually proxies, such as Whole Price Index, are used in efficiency analysis studies (see, e.g., Jamasb et al., 2018; Llorca et al., 2016). Weighted Average Capital Cost ($WACC$) is another measure which can be considered to define capital price and as in the case of Italy, the Italian energy regulator sets periodic $WACC$ to be used by utilities when reporting their *Capex*. Although we have data on the $WACC$ values and the Whole Price Index for the period 2011-2015, when this variable is utilised as capital price, the model does not converge, forcing us to elaborate the capital price using the available firm-level data.

normalised using the labour price. In order to control for the distinction made by the regulator based on the geographic area in which the utilities are located, two variables, *Centre* and *South* are included as dummies. To control for the fact that some utilities operate in more than one region a dummy variable (*Multiregion*) is included in the model. The dummy variable, Mountain Side (*Mount*), accounts for geographic characteristics of the firms. We control for the legal status of the utilities (i.e., whether the utility is registered as municipality/cooperative or corporation) by including Corporate (*Corp*) as a dummy variable in the cost function. Finally, a time trend (*T*) is added to the frontier to account for technical change.

A total of 8 variables are included as inefficiency determinants. Except for another time trend and a dummy variable that represents utilities operating in the northern area (*North*), all the other variables are measured at regional-level. Regional Gross Value Added per capita (*GVA*) captures the impact of regional economic development on firms' performance.

In order to examine our main hypothesis on whether institutional factors affect performance of network industries, we use regional-level institutional quality indexes. These indexes are assigned to each utility based on the region in which the headquarter of the utility is located in. As discussed by Kaufmann et al. (2011), country-level institutional quality measures can be used to define the concept of governance itself as well as the overall quality of governance in a country. According to Nifo and Vecchione (2014), the methodology can be applied to measure local-level quality of governance. Lasagni et al. (2015) use the weighted average of regional-level indexes introduced by Nifo and Vecchione (2014) (defined as Institutional Quality Index, *IQI*) to analyse performance of manufacturing firms in Italy. Borghi et al. (2016) use government effectiveness as well as regulatory quality indices at country-level to study performance of electricity distribution utilities across 16 European countries.

We use all five of these local-level institutional quality indexes: control of corruption (*Corru_Ctrl*), voice and accountability (*Voice*), rule of law (*RoL*), government effectiveness (*Gov_Eff*), and regulatory quality (*RQ*). Each of these indexes is considered to have an impact on firms' performance through either direct or indirect impacts. These impacts can include how a reliable justice system can assure a more secure business environment (rule of law), how a better control over corruption can reduce chances of free riding, how reforms are implemented or how business regulatory burdens and bureaucratic inefficiency can result in higher costs for business operations (regulatory quality). In general, with higher governance quality measures, firms tend to use their sources better. Therefore, the effect of these variables as inefficiency determinants is expected to be negative.

6. Results

We estimate a set of cost functions in our analysis. The first two are cost frontiers that are estimated following the approach proposed by Aigner et al. (1977), earlier defined as ALS model. We alternatively utilise Cobb-Douglas and translog functional forms for their specifications. These two cost functions do not incorporate inefficiency determinants. For the third one, we use the model labelled as RSCFG in Section 4, which incorporates inefficiency determinants. Table 2 presents the parameter estimates of the three cost functions.[21]

The ALS model with Cobb-Douglas specification is presented in the first column. In this model, the coefficients of two of the outputs, Energy Delivered and Number of Customers, are both positive and significant as expected, indicating the rise of total cost with increasing number of consumers and demand for energy. Although not statistically significant, the coefficient for *SAIDI* is negative and the sign remains consistent within the other two models. This indicates that as utilities extend their efforts to reduce duration of interruptions, their costs increase (conversely, the higher is the duration of interruptions, the lower are the effort and total cost).[22] Furthermore, the sum of the two significant output coefficients (*ENED* and *CUST*) is 0.79, pointing out the existence of economies of scale in the Italian electricity distribution sector. Coefficient of price of capital is positive and significant. The area dummies, *Centre* and *South*, are both positive, indicating that firms in central and southern areas have higher total costs relative to those in northern regions. However, only the coefficient for *Centre* is statistically significant. As expected, the dummy variable for mountain side (*Mount*) shows a positive and significant coefficient. The dummy variables for legal status (*Corp*) and utilities active in more

[21] Table C.1. is included in Appendix C to demonstrate the consistency of the estimates after adding the institutional variables in the RSCFG model: *Gross Value Added, North, T* and *Voice* are added in the RSCFG1 as inefficiency determinants and then, step by step, *Geff, RQ, RoL* and *Corru* are added in the following models. As it can be seen in the table, the estimates in different specifications remain consistent both in terms of their significancy and sign.

[22] Due to the twofolded nature of such efforts, the sign of this variable cannot be expected prior to the estimation. Filippini and Wetzel (2014) argue that when using *SAIDI* as an output in the cost frontier, the short-term and long-term impacts on variable and total costs might defer. In the short run, *SAIDI* increases *Totex* but in the long run, the impact might be positive or negative depending on the level of effort that the utility uses to reduce outages and whether, in turn, these efforts reduce the overall operation and maintenance costs.

than one region (*Multiregion*) are not statistically significant in the Cobb-Douglas specification. Finally, time trend (*T*) is not significant indicating lack of technical change.

The second column of Table 2 presents the ALS model with translog specification. This model, which does not include inefficiency determinants, shows similar results to the ALS model with the Cobb-Douglas specification for all explanatory variables except for *SAIDI*. Although the coefficient sign for *SAIDI* remains negative, it now becomes statistically significant.

The third column reports the estimation results for the RSCFG model which incorporates inefficiency determinants. In order to identify the best specification to be used when estimating the RSCFG model, a Likelihood Ratio (LR) test is applied. This test can be applied to compare the models presented in this paper because they are nested. The results, reported at the bottom of Table 2, support the rejection of the Cobb-Douglas against the translog specification when the ALS model is estimated; hence we use the latter to estimate the RSCFG model. When comparing the ALS against the RSCFG model, the former is rejected according to the LR test and therefore the RSCFG with translog specification is our preferred model to be analysed.

Table 2. Parameter Estimates (models with *Totex* as dependent variable)

	ALS (Cobb-Douglas)			ALS (translog)			RSCFG (translog)		
Variable	***Est.***		***Std. Err.***	***Est.***		***Std. Err.***	***Est.***		***Std. Err.***
Frontier									
Intercept	-1.740	***	0.160	-1.886	***	0.161	-1.788	***	0.174
ln ENED	0.442	***	0.069	0.529	***	0.078	0.500	***	0.089
ln CUST	0.346	***	0.076	0.226	***	0.078	0.278	***	0.101
ln SAIDI	-0.039		0.026	-0.049	*	0.027	-0.061	***	0.019
ln (KPR/LPR)	0.293	***	0.032	0.412	***	0.031	0.437	***	0.031
$\frac{1}{2}$ (ln ENED)^2				-0.021		0.170	0.083		0.160
$\frac{1}{2}$ (ln CUST)^2				0.135		0.235	0.422	*	0.220
$\frac{1}{2}$ (ln SAIDI)^2				0.012		0.012	-0.001		0.015
$\frac{1}{2}$ [ln (KPR/LPR)^2]				0.128	***	0.025	0.115	***	0.028
ln ENED · ln CUST				-0.041		0.198	-0.229		0.185
ln ENED · ln SAIDI				-0.014		0.049	-0.027		0.038
ln ENED · ln (KPR/LPR)				-0.041		0.081	-0.009		0.088
ln CUST · ln SAIDI				0.055		0.050	0.074	*	0.039
ln CUST · ln (KPR/LPR)				0.032		0.094	-0.009		0.100
ln SAIDI · ln (KPR/LPR)				0.026		0.025	0.050	**	0.025
Centre	0.464	***	0.107	0.500	***	0.110	0.384	***	0.132
South	0.215		0.208	0.179		0.208	0.209		0.164
Mount	0.190	**	0.094	0.281	***	0.094	0.096		0.093

Corp	0.437		0.111	0.067		0.099	0.051		0.107
Multiregion	0.025		0.161	-0.085		0.163	-0.349	**	0.151
T	0.011		0.021	-0.001		0.019	-0.008		0.017
Noise term									
ln (σ_v^2)	-2.862	***	0.412	-3.183	***	0.517	-4.064	***	1.123
Lambda ($\lambda = \sigma_u/\sigma_v$)	3.073	***	0.114	3.177	***	0.121	-		-
Inefficiency term (variance)									
Intercept	-0.617	***	0.198	-0.872	***	0.228	16.14	**	7.029
ln GVA							2.160		3.486
Voice							-17.87	***	3.982
RoL							-9.431	***	3.193
Gov_Eff							2.738		3.255
Corru_Ctrl							-23.73	***	5.796
RQ							29.93	***	5.711
North							-0.863		1.125
T							0.055		0.096
Observations		237			237			237	
Log-likelihood		-163.165			-130.976			-102.514	
Chi-squared LR test		64.38 ***			56.92 ***			-	
Degrees of freedom		(10)			(8)			-	

Significance code: *p<0.1, **p<0.05, ***p<0.01

After incorporating the inefficiency determinants in the RSCFG model, coefficients of both outputs and input prices in the frontier keep the same sign and remain significant as in the ALS model with the translog specification. The dummy variables *Centre*, *South* and *Corp* show the same results as before while *Mount* becomes not significant in this model. The estimated coefficient for the dummy variable *Multiregion* is negative as in the translog specification but becomes significant after including inefficiency determinants in our final model. This indicates that the total cost for those utilities which are active in more than one region is lower. This can be attributed to the existence of economies of scale in the Italian electricity distribution sector.

Regarding the inefficiency determinants, the coefficient for the regional gross value added per capita (*GVA*) is not significant, which means that the performance of Italian electricity distribution utilities is not significantly affected by the economic development of the regions in which they are located. This result is contrary to findings of Jamasb et al. (2018) who show that the GDP of the different Indian states has a positive effect on the performance of the utilities. This might be due to different contexts of these two studies as their study is based on a developing country (India) and our work is within a developed country (Italy) with a higher and relatively less heterogeneous Gross Value Added across the country.

Looking at the institutional quality measures included in the efficiency term, the coefficients are all significant and with the expected signs with the exception of Government Effectiveness (*Gov_Eff*), which is not significant. Voice and accountability (*Voice*), which represents the degree of government's responsiveness towards citizens, has a negative and significant impact on inefficiency. This indicates that as the politicians become more accountable for their actions and consequently do not use their power to fulfil interests of certain groups, a more reliable service can be provided and resources will be allocated more efficiently in the electricity distribution sector (Scott and Seth, 2013).

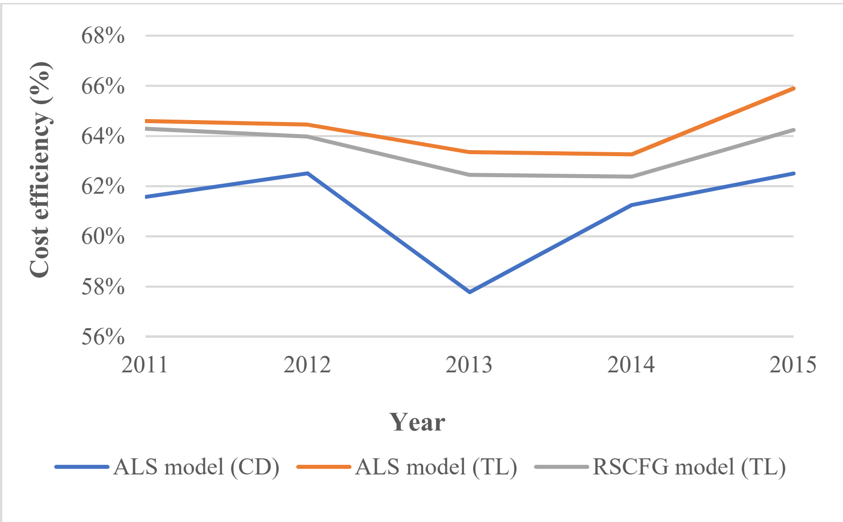
Similar result is found for the Rule of Law (*RoL*) coefficient which is significant and negative, suggesting that lower crime rates and higher quality of the court system can decrease firm-level inefficiency. This result is compatible with previous works on the impact of rule of law on business performance (Roxas et al., 2012). A stronger judiciary system will assure firms that their investment is not at risk and are encouraged to invest in less flexible but more efficient technologies (Bergara et al., 1998). The coefficient for Control of Corruption (*Corru_Ctrl*) is highly significant and negative. Italy has one of the lowest corruption perception index scores (equal to 50 in 2017) among the OECD countries (Transparency International, 2017), that is, the level of corruption is considered high, affecting firms' performance (Fiorino et al., 2012). Our result suggests that corruption has a negative impact on performance of regulated utilities. Consequently, as efforts to control corruption increases at macro-level, cost inefficiency in the electricity distribution sector decreases.

The coefficient for Regulatory Quality (*RQ*) is significant and positive which considering the definition of this index (footnote 16) is an expected outcome. Once again it should be noted that regulatory quality as an institutional index corresponds to the "the ability of a government to promote and formulate policies aiming at the development of firms and the private sector in general" (Nifo and Vecchione, 2014). This index is constructed by a combination of individual variables which indicate the business environment and the burdens/bureaucratic inefficiencies imposed on private business sector due to implementation of government policies. In this context, a positive sign for *RQ* indicates that where governments are less (more) successful in implementing "business regulations", i.e. the *RQ* index is higher (lower), then firm's inefficiency tend to be higher (lower).

Overall, the estimates suggest a strong impact of macroeconomic factors on the performance of distribution utilities. The coefficient of the control variable, *North*, is not significant, indicating that, once factors related to institutional quality are controlled, the area in which the utilities are located does not have an impact on their performance. Also, the time trend, *T*, does not have a significant impact on the efficiency of the utilities in our sample.[23]

Figure 1 shows how the average efficiency scores in the three estimated models change from 2011 to 2015. The figure shows more severe fluctuations in the efficiency scores during the period of analysis for the ALS model with Cobb-Douglas (CD) specification. However, since that model is rejected against the other two, we will focus only on the changes of the translogs. The efficiency scores of these models follow a similar pattern, and they are in general higher than the efficiency scores of the Cobb-Douglas specification. Throughout the period of analysis, the preferred RSCFG model, which includes inefficiency determinants, shows slightly lower efficiencies than the ALS model. The trend shows a steady decline in performance of utilities until 2013 and then the measures remained mostly the same in 2014 with an increasing drift in the following year in 2015.

Figure 1. Evolution of Annual Average Efficiency over Time



[23] In an alternative model, we replaced the time trend (*T*) with time dummies in the inefficiency term for the years of analysis in our sample (*YD2, YD3, YD4* and *YD5*). Table C.2. in Appendix C shows the estimates of that model, in which the coefficients for these time dummies are found to be not significant.

The average efficiency in the RSCFG model was 64% in 2011, when it started to decline, and reached the lowest of 62% in 2013 and 2014. It then increased in 2015 and reached an average efficiency score equal to 64.25%. The average efficiency score for the whole period is 63.43% which is lower than the 78% efficiency score of distribution utilities owned by *Enel* from 2004 to 2009, reported by Cambini et al. (2014).[24] This may be revealing the impact of economies of scale in the Italian electricity distribution sector. *Enel*, which owns 85% of the Italian electricity distribution sector, enjoys from its wide operation domain in the country. For this reason, it was considered to be an outlier of our sample and it was dropped from the analysis.

7. Conclusion

While the literature on how institutions impact performance of non-regulated firms is fairly rich, there is not sufficient empirical evidence on whether institutions affect the functioning of regulated network utilities. Our findings add to the literature by providing empirical evidence on the importance of good institutions in improving cost efficiency of electricity distribution utilities.

In Italy, electricity sector reforms began with two primary objectives: liberalisation and privatisation. After achieving these objectives in mid 2000s, the regulatory authority set eyes on improving efficiency as well as service quality of the electricity transmission and distribution sectors. However, after nearly two decades of reforms and regulatory efforts, the Italian electricity distribution sector still suffers from two main issues. First, there is a wide discrepancy between the performance of utilities across the country, and second, there is a persistent problem of electricity interruptions which is more common among the utilities located in southern parts of the country.

Northern and southern areas of Italy are historically diverse in terms of socioeconomic development measures. In addition, the geographical characteristics are quite disparate with northern parts mostly covered by mountains while southern areas are mostly coastal. According to the existing empirical evidence these factors affect the efficiency of electricity utilities and lead to efficiency differentials across a country. However, one strand of literature suggests that

[24] These efficiency scores are relative measures and hence they should be compared with caution.

performance differentials can be linked to differences in regional-level quality of institutions as well as macroeconomic factors such as GDP or GVA.

Using a unique dataset on the Italian electricity distribution utilities and estimating a set of stochastic frontier models, we analyse the cost efficiency of the electricity distribution utilities in different regions of Italy. We study the impact of regional-level economic development measures as well as the impact of quality of local institutions on the efficiency of the electricity distribution utilities. According to our estimations, the average cost efficiency of the Italian electricity distribution sector is on average around 64%. This score is lower than what has been reported by previous studies which did not incorporate the institutional or economic factors. Our results also suggest that regional-level macroeconomic factors as well as quality of regional institutions have significant impact on the cost efficiency of distribution utilities. In particular, utilities located in regions with better institutional endowments show better performance scores in comparison to the ones located in regions with lower institutional quality measurements.

The findings of this paper can be of interest to regulators as it is an attempt towards identifying unobservable roots of differences in performance of regulated firms such as electricity utilities. When applying benchmarking methods, regulators usually consider physical, organisational, and environmental (mainly meteorological) differences which can impact either capital or operational expenditures of the utilities. Following the results of this study, institutional diversity can also impact functioning of the utilities. Therefore, it appears that to compare performance of utilities on a fair basis when applying benchmarking methods, regional diversity in terms of institutional quality should be considered as well.

On the one hand, institutions directly and/or indirectly impact firms' operations through quality of the business environment. On the other hand, governments' accountability towards the citizens prevents distorted political actions as well as unfair resource allocation to preferred parties. If any of the institutional quality measures is weakened in a country or region, the abovementioned mechanisms might be negatively affected. Consequently, how resources are allocated and how utilities decide to use their available resources (i.e., whether they perform efficiently or inefficiently), are impacted as well.

In particular, in regions or countries that face issues such as low access rates due to unfair allocation of resources to the utilities or low service quality due to poor maintenance of operations by utilities, the problem might be linked to the quality of institutions. Thus, in order to overcome these issues and to improve the overall efficiency of the distribution sector, regulators need to consider the institutional domain that the utilities are encountering with. Current regulatory approaches do not take this into account and mainly focus on firm-level economic incentives and activities to improve the efficiency of the utilities. However, it appears that considering impacts of institutions is inevitable for devising effective incentives to regulated firms to improve their efficiency and quality of service. Nevertheless, in the long run, creating a more uniform institutional framework across all regions should be one of the main goals of the central government to avoid quality inconsistencies.

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Appendix A

Table A.1. Variables, Descriptions, and Sources

Variable Name	Label	Description	Data Source
Dependant Variable			
Totex	Total Distribution Cost	Total cost of distribution activities=*OPEX+CAPEX* *OPEX= Employees Cost+ Operations and Maintenance Cost+ Cost of Materials +Administrative and General Expenditure+ Other Costs* *CAPEX= Depreciation+ Interest*	Elaborated using data collected by ARERA.
Outputs			
ENED	Energy Delivered	Total energy delivered to customers.	Elaborated using data collected by ARERA.
CUST	Number of Customers	Total number of consumers served by the utility.	Elaborated using data collected by ARERA.
SAIDI	System Average Interruption Duration Index	Average duration of long (more than 3 minutes), unplanned interruptions per customer (measured in minutes).	ARERA Online Database: https://www.arera.it/it/dati/elenco_dati.htm.
Input Prices			
LPR	Labour Price	*Employees Cost/ Number of Personnel*	Elaborated using data collected by ARERA.
KPR	Capital Price	*Interest/Network Length*	Elaborated using data collected by ARERA.
Control Variables			
Corp	Corporation	Dummy variable that takes value 1 if the utility is not legally categorised as municipality or cooperative.	Elaborated using data collected by ARERA.
South	Southern area of Italy	Dummy variable that takes value 1 when a utility is located in the Southern area of the country.	Elaborated using data collected by ARERA.
Centre	Central area of Italy	Dummy variable that takes value 1 when a utility is located in the Central area of the country.	Elaborated using data collected by ARERA.
Mount	Mountain Side	Dummy variable that takes value 1 when a utility is located in a zone with the average altitude above 600 meters. ARERA classifies	Elaborated using data collected by ARERA.

		such zones as mountain-side.	
Multiregion	Multi-region Utilities	Dummy variable that takes value 1 when a utility is active in more than one region.	Elaborated using data collected from ARERA website.
Inefficiency Determinants			
GVA	Gross Value Added (per capita)	Regional Gross value added per capita.	Eurostat: https://ec.europa.eu/eurostat/data/database.
Corru_Ctrl	Control of Corruption	Index summarises the extent of efforts undertaken to control and reduce crimes committed against the Public Administration (PA) and to decrease the number of local administrations overruled by the federal authorities.	IQI Database: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
Gov_Eff	Government Effectiveness	Measures the endowment of social and economic structures in Italian provinces and the administrative capability of provincial and regional governments in terms of health policies, waste management and environment.	IQI Database IQI Database: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
RoL	Rule of Law	Summarises data on crime against persons or property, magistrate productivity, trial times, tax evasion and shadow economy.	IQI Database: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
RQ	Regulatory Quality	Comprises information concerning the degree of openness of the economy, business environment and, hence, the ability of local administrators to promote and protect business activity.	IQI Database: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
Voice	Voice and Accountability	The participation rate in public elections, the number of associations and of social cooperatives and cultural liveliness measured in terms of books published and purchased in bookshops.	IQI Database: https://siepi.org/en/institutional-quality-index-dataset-disponibile/.
North	Northern area of Italy	Dummy variable that takes value 1 when a utility is located in the Norther area of the country	Elaborated using data collected by ARERA.

Appendix B

Table B.1. Descriptive Statistics Based on Areas

		North				Centre				South			
Number of utilities		93				9				5			
Variable	***Unit***	***Min.***	***Max.***	***Mean***	***Std. Dev.***	***Min.***	***Max.***	***Mean***	***Std. Dev.***	***Min.***	***Max.***	***Mean***	***Std. Dev.***
Totex	Euros (2010)	5,656	172,077,190	8,157,150	23,573,705	53,832	315,185,156	44,248,718	102,521,291	34,567	6,581,187	2,297,865	2,780,361
ENED	MWh	0.67	113,34,422	320,608	1,281,097	1,790	10,957,132	1,265,112	3,336,375	3.21	155,839	28,624	57,929
CUST	No of Customers	10	1,122,467	39,219	144,003	802	1,626,019	193,560	509,330	614	33,610	6,595	11,650
SAIDI	Minutes	0.01	8,067	118.88	455.26	11	805	126.63	157.32	11	780	269.05	252.91
LPR	Euros (2010)	200	265,430	53,566	28,979	23,134	68,074	49,084	15,055	7,215	84,546	46,006	36,258
KPR	Euros (2010)	0.01	21,466	1,888	1,868	72	5,338	1,542	1,389	1,337	3,479	2,660	634
Mount	Dummy	0	1	0.85	0.36	0	1	0.11	0.32	0	1	0.60	0.50
Corp	Dummy	0	1	0.79	0.41	0	1	0.89	0.32	0	1	0.23	0.43
Multiregion	Dummy	0	1	0.02	0.14	0	0	0	0	0	0	0	0
GVA	Euros (2010)	23,957	33,822	31,604	3,227	19,848	30,620	24,080	3,198	14,295	21,902	16,671	2,329
Voice	Index	0.43	0.65	0.49	0.06	0.44	0.60	0.49	0.08	0.23	0.44	0.32	0.09
RoL	Index	0.30	0.79	0.71	0.12	0.62	0.67	0.64	0.02	0.40	0.82	0.52	0.16
RQ	Index	0.46	0.72	0.66	0.06	0.50	0.62	0.57	0.06	0.21	0.53	0.33	0.14
Gov_Eff	Index	0.32	0.61	0.49	0.04	0.29	0.41	0.37	0.05	0.17	0.29	0.23	0.05
Corru_Ctrl	Index	0.80	0.95	0.91	0.04	0.86	0.97	0.91	0.04	0.61	0.87	0.74	0.11

Appendix B

Table B.2. The Correlation Matrix

	Totex	Energy Delivered	Customers	SAIDI	Labour Price	Capital Price	North	Centre	South	Mountain Side	Private	Multiregion	GVA	Control of Corruption	Voice and Accountability	Rule of Law	Government Effectiveness	RQ
Totex	1	0.927	0.929	-0.096	0.015	0.226	-0.220	0.243	-0.015	-0.532	0.175	0.303	-0.248	-0.105	0.243	-0.334	-0.262	-0.247
Energy Delivered	0.927	1	0.983	-0.117	0.280	-0.001	-0.176	0.212	-0.049	-0.579	0.197	0.298	-0.258	-0.081	0.236	-0.347	-0.213	-0.242
Customers	0.929	0.983	1	-0.121	0.258	0.027	-0.190	0.212	-0.017	-0.590	0.215	0.329	-0.303	-0.165	0.272	-0.418	-0.213	-0.319
SAIDI	-0.096	-0.117	-0.121	1	-0.124	0.048	-0.146	0.110	0.103	0.061	0.155	-0.065	-0.125	-0.056	-0.063	-0.036	-0.077	-0.085
Labour Price	0.015	0.280	0.258	-0.124	1	-0.534	0.060	-0.024	-0.087	-0.083	0.087	0.067	-0.018	0.005	0.053	-0.057	0.037	-0.042
Capital Price	0.226	-0.001	0.027	0.0481	-0.534	1	0.024	-0.085	0.132	0.016	-0.110	0.152	0.102	-0.125	0.191	-0.039	-0.028	-0.035
North	-0.220	-0.176	-0.190	-0.146	0.060	0.024	1	-0.908	-0.372	0.496	-0.041	0.082	0.709	-0.011	0.251	0.176	0.676	0.403
Centre	0.243	0.212	0.212	0.110	-0.024	-0.085	-0.908	1	-0.052	-0.450	0.115	-0.075	-0.528	0.132	-0.137	-0.102	-0.524	-0.201
South	-0.015	-0.049	-0.017	0.103	-0.087	0.132	-0.372	-0.052	1	-0.184	-0.155	-0.030	-0.517	-0.265	-0.292	-0.193	-0.449	-0.514
Mountain Side	-0.532	-0.579	-0.590	0.061	-0.083	0.016	0.496	-0.450	-0.184	1	-0.195	-0.263	0.636	0.160	-0.089	0.619	0.297	0.509
Corp	0.175	0.197	0.215	0.155	0.087	-0.110	-0.041	0.115	-0.155	-0.195	1	0.067	-0.133	-0.129	0.112	-0.209	0.066	-0.164
Multiregion	0.303	0.298	0.329	-0.065	0.067	0.152	0.082	-0.075	-0.030	-0.263	0.067	1	-0.175	0.106	-0.126	-0.151	-0.012	-0.113
GVA	-0.248	-0.258	-0.303	-0.125	-0.018	0.102	0.709	-0.528	-0.517	0.636	-0.133	-0.175	1	0.298	0.336	0.615	0.399	0.780
Control of Corruption	-0.105	-0.0819	-0.165	-0.056	0.005	-0.125	-0.011	0.132	-0.265	0.160	-0.129	0.106	0.298	1	-0.400	0.682	-0.217	0.702
Voice and Accountability	0.243	0.236	0.272	-0.063	0.053	0.191	0.251	-0.137	-0.292	-0.089	0.112	-0.126	0.336	-0.400	1	-0.325	0.148	0.0755
Rule of Law	-0.334	-0.347	-0.418	-0.036	-0.057	-0.039	0.176	-0.102	-0.193	0.619	-0.209	-0.151	0.615	0.682	-0.325	1	-0.127	0.748
Government Effectiveness	-0.262	-0.213	-0.213	-0.077	0.037	-0.028	0.676	-0.524	-0.449	0.297	0.066	-0.0120	0.399	-0.217	0.148	-0.127	1	0.102
RQ	-0.247	-0.242	-0.319	-0.085	-0.042	-0.035	0.403	-0.201	-0.514	0.509	-0.164	-0.113	0.780	0.702	0.075	0.748	0.102	1

Appendix C

Table C.1. Step by Step Inclusion of Institutional Variables in the RSCFG Model

	Models						
Variable	**ALS (Cobb -Douglas)**	**ALS (translog)**	**RSCFG1**	**RSCFG2**	**RSCFG3**	**RSCFG4**	**RSCFG5**
Frontier							
Intercept	-1.740***	-1.886***	-1.772***	-1.792***	-1.695***	-1.812***	-1.788***
	(0.160)	(0.161)	(0.155)	(0.153)	(0.128)	(0.162)	(0.174)
ln ENED	0.442***	0.529***	0.458***	0.475***	0.487***	0.477***	0.500***
	(0.069)	(0.078)	(0.087)	(0.087)	(0.084)	(0.092)	(0.089)
ln CUST	0.346***	0.226***	0.319***	0.307***	0.310***	0.317***	0.278***
	(0.076)	(0.078)	(0.086)	(0.087)	(0.082)	(0.098)	(0.101)
ln SAIDI	-0.039	-0.050*	-0.048**	-0.049**	-0.048**	-0.054***	-0.062***
	(0.026)	(0.027)	(0.022)	(0.022)	(0.019)	(0.019)	(0.019)
ln (KPR/LPR)	0.293***	0.413***	0.406***	0.418***	0.441***	0.436***	0.437***
	(0.032)	(0.031)	(0.035)	(0.035)	(0.038)	(0.037)	(0.031)
$\frac{1}{2}$ (ln ENED)^2		-0.021	0.0082	0.025	0.082	0.082	0.083
		(0.170)	(0.148)	(0.148)	(0.142)	(0.151)	(0.160)
$\frac{1}{2}$ (ln CUST)^2		0.135	0.190	0.238	0.479**	0.407*	0.422*
		(0.235)	(0.221)	(0.222)	(0.216)	(0.220)	(0.220)
$\frac{1}{2}$ (ln SAIDI)^2		0.013	0.001	0.001	0.001	-0.003	-0.001
		(0.013)	(0.016)	(0.016)	(0.016)	(0.017)	(0.016)
$\frac{1}{2}$ [ln (KPR/LPR)^2]		0.128***	0.123***	0.123***	0.105***	0.112***	0.115***
		(0.025)	(0.026)	(0.027)	(0.027)	(0.032)	(0.027)
ln ENED · ln CUST		-0.0407	-0.084	-0.115	-0.257	-0.223	-0.229
		(0.198)	(0.179)	(0.179)	(0.173)	(0.177)	(0.185)
ln ENED · ln SAIDI		-0.014	-0.033	-0.031	-0.033	-0.034	-0.027
		(0.048)	(0.042)	(0.042)	(0.037)	(0.036)	(0.038)
ln ENED · ln (KPR/LPR)		-0.039	-0.049	-0.042	-0.078	-0.026	-0.008
		(0.081)	(0.083)	(0.082)	(0.078)	(0.089)	(0.087)
ln CUST · ln SAIDI		0.055	0.078*	0.075*	0.086**	0.077**	0.074*
		(0.050)	(0.044)	(0.044)	(0.039)	(0.039)	(0.039)
ln CUST · ln (KPR/LPR)		0.031	0.045	0.034	0.065	0.009	-0.008
		(0.094)	(0.098)	(0.097)	(0.091)	(0.101)	(0.099)
ln SAIDI · ln (KPR/LPR)		0.026	0.026	0.029	0.048*	0.042*	0.051**
		(0.024)	(0.026)	(0.026)	(0.025)	(0.0256)	(0.025)
Centre	0.464***	0.500***	0.419***	0.408***	0.222*	0.354**	0.384***
	(0.107)	(0.110)	(0.129)	(0.135)	(0.119)	(0.157)	(0.132)
South	0.215	0.179	0.112	0.144	0.068	0.208	0.209
	(0.208)	(0.208)	(0.184)	(0.177)	(0.117)	(0.177)	(0.164)
Mount	0.190**	0.281***	0.128	0.150*	0.055	0.141	0.096
	(0.094)	(0.093)	(0.090)	(0.090)	(0.077)	(0.094)	(0.092)
Corp	0.043	0.067	0.030	0.026	-0.009	0.017	0.050
	(0.111)	(0.099)	(0.102)	(0.100)	(0.099)	(0.104)	(0.107)

Multiregion	0.025	-0.085	-0.223	-0.237	-0.539***	-0.425**	-0.349**
	(0.161)	(0.163)	(0.166)	(0.166)	(0.172)	(0.191)	(0.151)
T	0.011	-0.001	-0.005	-0.008	-0.019	-0.011	-0.008
	(0.021)	(0.019)	(0.020)	(0.020)	(0.018)	(0.019)	(0.017)
Noise term							
ln (σ_v^2)	-2.862	-3.183***	-3.693***	-3.710***	-3.839***	-4.120***	-4.064***
	(0.412)	(0.517)	(0.527)	(0.557)	(0.511)	(1.046)	(1.123)
Lambda ($\lambda = \sigma_u/\sigma_v$)	3.073***	3.177***	-	-	-	-	-
	(0.114)	(0.121)	-	-	-	-	-
Intercept	-0.617***	-0.872***	2.190**	1.076	-10.27***	-1.858	16.14**
	(0.198)	(0.228)	(1.074)	(1.419)	(3.697)	(4.667)	(7.029)
ln GVA			2.456**	2.852***	-2.902	1.576	2.160
			(1.057)	(1.103)	(2.007)	(2.675)	(3.486)
North			-0.130	-0.670	-0.344	-0.506	-0.863
			(0.562)	(0.725)	(0.764)	(0.844)	(1.125)
T			0.043	0.050	0.072	0.074	0.055
			(0.092)	(0.094)	(0.090)	(0.092)	(0.096)
Voice			-5.739***	-5.084***	-5.693***	-10.12***	-17.87***
			(1.822)	(1.931)	(1.856)	(2.822)	(3.982)
Gov_Eff				2.627	9.562***	4.914	2.738
				(2.158)	(3.158)	(3.005)	(3.255)
RQ					12.49***	13.18***	29.93***
					(3.639)	(3.999)	(5.711)
RoL						-6.197**	-9.431***
						(2.920)	(3.193)
Corru_Ctrl							-23.73***
							(5.796)
Observations	237	237	237	237	237	237	237
Log-likelihood	-163.165	-130.976	-123.500	-122.753	-116.111	-114.080	-102.514

Significance code: *p<0.1, **p<0.05, ***p<0.01

Appendix C

Table C.2. Analysis including time dummies instead of time trend in the inefficiency term.

	ALS (Cobb-Douglas)			ALS (translog)			RSCFG (translog)		
Variable	***Est.***		***Std. Err.***	***Est.***		***Std. Err.***	***Est.***		***Std. Err.***
Frontier									
Intercept	-1.740	***	0.160	-1.886	***	0.161	-1.806	***	0.175
ln ENED	0.442	***	0.069	0.529	***	0.078	0.495	***	0.091
ln CUST	0.346	***	0.076	0.226	***	0.078	0.283	***	0.104
ln SAIDI	-0.039		0.026	-0.049	*	0.027	-0.066	***	0.019
ln (KPR/LPR)	0.293	***	0.032	0.412	***	0.031	0.433	***	0.032
$^1/_2$ (ln ENED)^2				-0.021		0.170	0.076		0.160
$^1/_2$ (ln CUST)^2				0.135		0.235	0.398	*	0.217
$^1/_2$ (ln SAIDI)^2				0.012		0.012	0.001		0.015
$^1/_2$ [ln (KPR/LPR)^2]				0.128	***	0.025	0.116	***	0.027
ln ENED · ln CUST				-0.041		0.198	-0.215		0.183
ln ENED · ln SAIDI				-0.014		0.049	-0.028		0.038
ln ENED · ln (KPR/LPR)				-0.041		0.081	-0.007		0.088
ln CUST · ln SAIDI				0.055		0.050	0.075	*	0.038
ln CUST · ln (KPR/LPR)				0.032		0.094	-0.008		0.100
ln SAIDI · ln (KPR/LPR)				0.026		0.025	0.050	**	0.025
Centre	0.464	***	0.107	0.500	***	0.110	0.403	***	0.133
South	0.215		0.208	0.179		0.208	0.228		0.166
Mount	0.190	**	0.094	0.281	***	0.094	0.108		0.091
Corp	0.437		0.111	0.067		0.099	0.058		0.107
Multiregion	0.025		0.161	-0.085		0.163	-0.327	**	0.147
T	0.011		0.021	-0.001		0.019	-0.007		0.018
Noise term									
ln (σ_v^2)	-2.862	***	0.412	-3.183	***	0.517	-4.091	***	1.156
Lambda ($\lambda = \sigma_u/\sigma_v$)	3.073	***	0.114	3.177	***	0.121	-		-
Inefficiency term (variance)									
Intercept	-0.617	***	0.198	-0.872	***	0.228	17.17	**	7.107
ln GVA							2.664		3.442
Voice							-18.77	***	4.076
RoL							-9.947	***	3.198
Gov_Eff							2.528		3.199
Corru_Ctrl							-24.04	***	5.827
RQ							29.90	***	5.710
North							-0.917		1.146
YD2							0.157		0.343
YD3							0.343		0.320
YD4							0.479		0.364
YD5							0.047		0.392
Observations		237			237			237	
Log-likelihood		-163.165			-130.975			-101.222	

Significance code: *p<0.1, **p<0.05, ***p<0.01