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EXPLORING HOSPITAL EFFICIENCY WITHIN AND BETWEEN ITALIAN REGIONS: NEW EMPIRICAL EVIDENCE

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Exploring hospital efficiency within and between Italian regions: new empirical evidence

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Abstract

This paper investigates the efficiency of Italian hospitals and how their performances have changed over the years 2007-2016, characterized by the great economic recession and budget constraints. We apply the Benefit of Doubt (BoD) approach to determine a composite index that considers the multi-dimensionality of the hospital outcome to be used as main output in a metafrontier production function based on a stochastic frontier framework. The efficiency score distribution is then used to construct a Theil index in order to compare over time the inequality of the estimated efficiency between hospitals, both within and between regions. The main findings show that the primary source of inefficiency comes from managerial inefficiency especially for hospitals located in southern regions. A clear and persistent North-South gap in efficiency performances of hospitals has been found along with an increase in the inequality in terms of efficiency between the areas of the country mostly determined by between region inequality.

Keywords: Benefit of Doubt, MetaFrontier, Health Efficiency, Regional Inequality
JEL codes: I14; I18; C67

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1 Introduction

The Italian National Health Service (NHS), introduced in 1978, is a universal health care system providing comprehensive health insurance coverage and uniform health benefits to the whole population. It is inspired by the two fundamental pillars enshrined in Article 32 of the Italian Constitution: universality and equality. While the principle of universality has never been questioned, the principle of equality, especially if broken down into terms of equality of services in the local territories, has been repeatedly overlooked in recent years. The last decade has been characterized by the profound financial crisis, exacerbating the economic differences between North and South (see about this aspect Lagravinese (2015)) with inevitable effects also on the demand and supply of health. Indeed, inequalities have started to increase again with evident effects on available healthcare resources, on the quality of uneven healthcare services, and on the living conditions of citizens. Since its introduction, and as in other European countries (see Costa-Font and Greer (2013)), the Italian NHS has undergone important reforms to decentralize health management and policy responsibilities to the sub-layers of government (Turati, 2013). The governing of the healthcare system in Italy is passed on to the 20 regions. After one of the most important federal reforms (Legislative Decree 56/2000), each region is in charge of organization of the health system, following the general guidelines defined by the central government that is responsible for defining the Essential Levels of Health Services (LEA, *Livelli Essenziali di Assistenza*). LEA is a list of health care services that the central government requires to be guaranteed in all regions[1]. However, the separation of financing responsibilities from expenditure responsibilities in the provision of LEA, and before LEA in the provision of uniform levels of service, has provided a non-negligible incentive to the uncontrolled growth of Italian health expenditures and has historically contributed to creating bailing out expectations in regional behavior (Liberati, 2003), especially in a context of often inadequate regional health governance and accountability (Carinci et al., 2012). Many of the regional health plans are aimed at implementing the so-called hub and spoke model. This organizational model is characterized by the concentration of highly complex assistance in centers of excellence (hub) supported by a network of services (spoke) which are responsible for selecting patients and sending them to reference centers when a certain threshold of clinical-care severity is overcome.

Recently, the tensions caused by the COVID-19 pandemic have led to a reconsideration of the health system policies implemented in the past. Many of the public policies concerning a reduction in beds, a significant reduction in medical and nursing staff, hospital mergers and acquisitions as well as lower investments in infrastructure are now subject to revaluation not only in Italy but in general also in other countries which in recent years have experienced cuts and reorganizations of the NHS (such as UK, Spain etc.). Even the decentralized organization itself has been questioned and in many cases, possible scenarios of re-centralization of the health system have been analyzed as in the past for Scandinavian countries (Mosca, 2007). With regard to this issue, Italy is one of the western countries that has significantly reduced healthcare spending by reshaping its hospital organization and decentralizing management and spending choices at regional level. The effects of these

[1]LEA list was recently updated by a ministerial decree in 2017.

policies are still controversial to this day, but what is undoubtedly an established fact is that the inequalities between the regional systems in these 20 years have not diminished and the economic crises and austerity policies have not reduced the territorial gaps in the country. Furthermore, the recovery plans imposed by the central government in 2007 for the regions with high deficits have certainly favored the reduction of healthcare expenditures and have proved to be an effective mechanism for eliminating sub-national governments deficits (Bordignon et al., 2020). However, there is still no clear consensus in the literature whether those recovery plans, and in general the decentralization process, have also had an impact on increasing health inequalities between or within regions. Our work attempts to enrich this literature. In particular, our study looks at whether hospital efficiency (which has been at the heart of the reorganization by the regions) has changed over the last decade. We therefore first investigate the technical efficiency of hospitals in two different periods and then comparing whether the efficiency performance of hospitals has improved or not between and within the regions.

The economic literature has so far produced a rich and consolidated series of works to study hospital efficiency (parametric and non-parametric approaches)[2]. More specifically, as far as the studies that have analyzed Italian hospitals are concerned, most of them have investigated how efficiency has changed with the introduction of new accounting systems such as the use of the diagnostic-related groups (Barbetta et al., 2007; Cavalieri et al., 2016) or how efficiency has changed due to the ownership of hospitals (Cellini et al., 2000; Colombi et al., 2017; Daidone and D'Amico, 2009). To the best of our knowledge, there are no studies that measure in a more holistic way how efficiency has changed over the years and whether the regional policies have actually reduced the differences in hospitals between and within regions. This paper attempts to fill this gap. In particular, the aim of the present study is twofold.

The first contribution of the paper regards the methodology used to measure the efficiency of the hospitals. We apply the benefit of doubt (BoD) approach to determine a composite index that considers the multi-dimensionality of the hospital outcome. Indeed, as far as we know, the BoD has received scarce attention so far in the health care sector. In detail, the BoD aggregates linearly quantitative performance sub-indicators into a single composite one using the combination of weights that is the most convenient for the evaluated Decision Making Unit (DMU) (Cherchye et al., 2007). For each evaluated DMU, this is done by implicitly assigning less (more) weight to those sub-indicators or aspects of performance that the particular DMU is relatively weak (strong) when compared with all other DMUs in the sample (Karagiannis and Paschalidou, 2017). For this reason, decision makers should not be worried about unfair weighting schemes since each DMU is put in its most favorable condition, since any other weighting scheme would generate a lower composite index (Cherchye et al., 2007). Thanks to its high flexibility in terms of exogenous assumptions for setting weights, the BoD can be used to take into account the specializations of individual hospitals (see sub-section 3.3. for more details on the BoD concept). Additionally, the composite indicator generated by the BoD is then used as output in a metafrontier

[2]The substantial difference between the studies lies in the choice of parametric (e.g. Stochastic Frontier) or non-parametric (Data Envelopment Analysis, Corrected Ordinary Least Squares) methods in estimating the production or cost function.

production function based on a stochastic frontier framework[3]. More specifically, we apply a two-step stochastic frontier approach recently developed by Huang et al. (2014). The meta-production function is based on the idea that hospitals have access, potentially, to different production technologies in different time periods, being differently conditioned by several factors such as, for instance, environmental characteristics, regulation and the availability of resources. The stochastic metafrontier approach disentangles the group-specific frontiers and the metafrontier, further decomposing the efficiency scores of various groups of hospitals into technical efficiency scores and technology gaps (see Section 2 for more details on the procedure used). The analysis is carried out using hospital data over almost one decade: in 2007, the year before the great recession and when, with the introduction of the recovery plans[4], a number of regions had to substantially reconsider their offer on the territory and in 2016, the last year for which the data are available in detail for all Italian healthcare facilities. To account for the change in efficiency between the two years, the metafrontier has been used. To the best of our knowledge, this is the first work to apply this methodology in the Italian hospital context. The main findings show that the primary source of inefficiency comes from managerial inefficiency especially for hospitals located in southern regions.

The second contribution of the paper is an attempt to link the literature regarding the hospitals' efficiency, and inequality in the healthcare services at local level. The efficiency score distribution is employed to compute the Theil index (Theil, 1967), a perfect decomposable inequality index, to compare over time the inequality of the estimated efficiency between hospitals in the same region and between different regions. The results of this analysis allow us to make some more general considerations regarding the evolution of the healthcare services in Italy. The findings show a clear and persistent North-South gap in efficiency performances of hospitals along with an increase in the inequality in terms of efficiency between the areas of the country mostly determined by between region inequality. The empirical evidence provides helpful recommendations for policy makers regarding whether local level provision of hospital services should be improved or whether the regional policies implemented in these years should be reconsidered in order to favor a convergence process.

The rest of the paper is organized as follows. The next section describes the methodology employed, Section 3 presents the data and provides some descriptive statistics, Section 4 discusses the results both in the metafrontier and inequality analyses and finally, Section 5 concludes and offers some policy implications.

[3]The use of a single composite outcome allows us to take into account the complexity of the hospitals in the production function, avoiding a limit of the Stochastic Frontier Analysis, for example, the use of a single output for each production function.

[4]Some regions were subject to specific recovery plans, called "Piani di Rientro", implemented to recover from budget deficit related to health expenditures (we take into account the presence of these plans when measuring the efficiency of the hospitals as explained in more detail in sub-section 3.2).

2 Methodology

2.1 Efficiency of hospitals

We calculate the hospital's relative efficiency at converting inputs into a production set while maximizing outputs. Two main methods have been extensively applied in the literature to measure efficiency – non-parametric[5] and parametric[6] – and no consensus has been reached on which one should be adopted to measure the efficiency of healthcare provision institutions. Both approaches have their advantages and disadvantages (Hollingsworth, 2008; Lewin and Lovell, 1990) and construct a theoretical production frontier, but they do so in a different way. The parametric method approach is characterized by the assumption of a functional form for the underlying production function, that is, the assumption of a common technology (e.g. Ces, Translog). In addition, specific assumptions are made about the error term distribution (truncated or one side distribution). Under these assumptions, single (or input demand system) regression yields marginal products, marginal cost or partial elasticities from which an efficiency index can be constructed. On the contrary, the non-parametric approach does not require the underlying production function to belong to any specific functional form. It does not require any assumption on the error term either, because it assumes that any deviation from frontier is due to inefficiency. This very last assumption, while exposing the procedure to errors from poor data quality, provides a way to economize on data requirements and because of this makes efficiency analysis possible even when other methods of estimation would not be applicable (Patrizii and Resce, 2013).

We follow the procedure proposed by Huang et al. (2014) by applying a two-stage parametric approach and estimate a metafrontier production function based on a stochastic frontier framework. This technique estimates technical efficiency scores for hospitals in different groups adopting different technologies. We believe that hospitals in 2007 and in 2016 are not generated from a single production frontier, implying that they do not adopt the same underlining technology. Therefore, it could be necessary to estimate the metafrontier production function. This procedure allows us to assess both the group-specific frontiers (hospitals in 2007 and hospitals in 2016) and the metafrontier (for both periods)[7]. More specifically, this approach decomposes the efficiency scores of the two groups into technical efficiency scores and technology gaps. Unlike other methods, the metafrontier estimation is a stochastic metafrontier (SMF) regression method, with some important computational advantages. First, the usual statistical inferences can be performed without relying on simulations or bootstrap methods, as opposed to mathematical programming techniques. Indeed, it applies the conventional maximum likelihood method to estimating

[5]For example, data envelopment analysis (DEA) and free disposable hull (FDH), proposed by Charnes et al. (1978) using the original contribution of Farrell (1957), based on deterministic frontier models (see also Cazals et al. (2002)).

[6]For example, a stochastic frontier approach (SFA), a distribution-free approach (DFA) and a thick frontier approach (TFA), based on stochastic frontier models (see Aigner et al. (1977)).

[7]Note that the main difference between the method proposed by Huang et al. (2014) and that of Battese et al. (2004) and O'Donnell et al. (2008) is that the former's second-step estimation of the metafrontier is still based on the stochastic frontier framework, rather than on a mathematical programming technique.

the parameters of the SMF regression. Second, the metafrontier makes it possible to directly estimate the technology gaps by treating them as a conventional one-sided error term. This strategy allows us to separate the random shocks from the technology gaps, a well-known advantage of the stochastic frontier technique over the programming technique.

2.2 The stochastic frontier analysis

To estimate hospital technical efficiency, we rely on the parametric approach, such as the stochastic frontier approach (SFA). Through this method, a frontier is estimated on the relation between inputs and outputs. This can be, for example, a linear function, a quadratic function or a translog function. We use a more general functional form, that is, the transcendental logarithmic or "translog" (see Barbetta et al. (2007); Colombi et al. (2017)), for the frontier production function. The translog functional form may be preferred to the Cobb-Douglas form because of the latter restrictive elasticity of substitution and scale properties, and it allows for non-linear causalities, compared with the more simple Cobb-Douglas function. This method has become a common technique in order to assess production and inefficiencies in the production of good and services in different context, such as economics, health, education, and energy sectors. The methodology employed in this paper is developed by Huang et al. (2014). In a general canonical form, the stochastic frontier model is described by the following set of equations:

$$Y_{it} = x_{it}^{'}\beta + \epsilon_{it} \tag{1}$$

$$\epsilon_{it} = \nu_{it} - u_{it} \tag{2}$$

$$\nu_{it} \sim N(0, \sigma_{\nu}^2) \tag{3}$$

$$u_{it} \sim N^{+}(0, \sigma_u^2) \tag{4}$$

where y denotes the output of the i_{th} hospital at time t, x_i is $1xk$ vector of input of the i_{th} hospital at time t, β is $kx1$ vector of unknown parameters to be estimated, u_{it} denotes the short-term inefficiency distributed by each unit as half normal, and ν_{it} is a stochastic component. The model described in the system of equations (1) - (4) is estimated by means of Maximum-Likelihood methods. The technical efficiency is calculated as the ratio of the observed output and the maximum feasible output on the production frontier. Formally:

$$TE_{it} = \frac{y_{it}}{\hat{y}_{it}} = \frac{x_{it}^{'}\beta + \epsilon_{it}}{x_{it}^{'}\beta + \nu_{it}} \tag{5}$$

where $\hat{y}_{it}$ is the maximum feasible output that lies on the production frontier.

2.3 Metafrontier model

The Metafrontier model is developed by Battese et al. (2004) and O'Donnell et al. (2008). Basically, this procedure is based on two stages. In the first stage, the group-specific frontiers frontiers (i.e. hospitals in 2007 and 2016) are estimated by means of a stochastic frontier model as in the system of equations (1) – (4) for each hospital. The estimated parameter β associated to the pooled stochastic frontier model in the system of equations (1) – (4) changes to β^j for each group j. In the second stage, a metafrontier is enveloped over the frontiers associated to each year (see for more details about the metafrontier optimization (O'Donnell et al., 2008)).

We calculate the technical efficiency (TE) associated to the metafrontier in order to compare the efficiency scores of the hospitals across different technology sets (frontiers). Formally:

$$TE^*_{i(j)} = \frac{y_{i(j)}}{y^*_i} = \frac{x'_{i(j)}\beta_j + \epsilon_{i(j)}}{x'_i\beta^*} \tag{6}$$

where y^*_i denotes the output on the metafrontier, while $TE^*_{i(j)}$ represents the ratio of the observed output of hospital i in group j to the metafrontier output.

The technology gap ratio ratio (TGR), described by the ratio of the output of the production function for hospital i relative to the potential output of the metafrontier for a given set of input variables, is as follows:

$$TGR_{i(j)} = \frac{TE^*_{i(j)}}{TE_{i(j)}} \tag{7}$$

In particular, TGR captures the difference between the productivity of the group and the metatechnology (i.e. the technology available to all hospitals) (see for more details the geographical representation associated to metafrontier in O'Donnell et al. (2008)).

Finally, the two previous terms can be also used to calculate the hospital technical efficiency with respect to the metafrontier production technology as opposed to the hospital's technical efficiency with respect to the group-j production technology (MTE), as follows:

$$MTE_{i(j)} = TGR_{i(j)} * TE_{i(j)} \tag{8}$$

2.4 Inequality in efficiencies scores over time

In order to investigate inequality in terms of efficiency scores, we use the results of MTE. The distribution in the two periods is then computed disentangling between and within regions inequality using the Theil index (Theil, 1967), which is a perfectly decomposable inequality index, as follows:

$$TI = \sum_i f_i(\frac{\tau_i}{\mu})log(\frac{\tau_i}{\mu}) \tag{9}$$

where f_i is the group of hospital i, τ_i is the efficiency index of the hospital i.

The index in equation (9) can be decomposed into a between and within group component as follows:

$$TI = [\sum_j g_j(\frac{\mu_j}{\mu})log(\frac{\mu_j}{\mu})] + \sum_j TI_j g_j(\frac{\mu_j}{\mu}) \tag{10}$$

where j refers to the sub-group, g_j is the share of group j and TI_j is the inequality in group j. The between component of inequality is captured by the first term, i.e., the level of inequality if everyone within each group j had efficiency level μ_j, the second term gives the within component of inequality (Cowell, 2000; Elbers et al., 2005).

3 Data

3.1 Inputs and Outputs

The data were collected by the Ministry of Health for 2007 and 2016. The dataset for 2016 can be consulted directly by downloading it from the government website whereas for the 2007 data, the Archive Internet Wayback Machine on the Ministry of Health website was used.

Data include information on different inputs and outputs usually considered in the studies on hospital efficiency (see, for instance, Barbetta et al. (2007); Cavalieri et al. (2016); Colombi et al. (2017); Herwartz and Strumann (2014); Widmer (2015)) with regard to 403 hospitals followed in two years (more specifically, we collect data on 29 accredited, 42 private and 332 public hospitals).

More specifically, four measures of inputs are included in the model. The first three measures reflect the number of personnel units such as the number of physicians (*Physicians*); the number of nurses (*Nurses*); and the number of other personnel (Other). The fourth input refers to a measure of capital such as the number of available beds (*Beds*). With regard to the output side, three measures of outputs are included in the model, such as the number of discharged patients (*Discharged Patients*), the number of inpatient days (*Inpatient Days)*, and the number of emergency room treatments (*Emergy Room Treatments*).

Weighting outputs according to case-mix has been acknowledged as vital, particularly when the sample consists of hospitals of different sizes, or university hospitals together with other acute hospitals, to minimizing intra-hospital as well as inter-hospital differences (Chowdhury et al., 2014). To take this issue into account, all the outputs are normalized using diagnostic-related groupings (Chowdhury and Zelenyuk, 2016).

3.2 Variability of (in)efficiency

It seems inappropriate to assume that efficiency will vary for each hospital in the same way. Institutions can react in very different ways to the contexts they operate in. To take into account the effects of factors that affect the performance of hospitals, we include a vector of exogenous variables in the variance of the efficiency term (see Colombi et al. (2017)).

First of all, we take into account the impact of ownership on hospital performances. In general, private ownership characterized by the presence of residual claimants should represent a powerful incentive to economic efficiency and cost reduction; on the contrary, public ownership and/or the absence of any claimant of residual earnings may induce shirking and could decrease effort, consequently reducing efficiency (Barbetta et al., 2007). We use a dummy variable taking the value of 1 in case the hospital has a private/accredited private health care (*Private*) ownership, and 0 otherwise.

Second, we also take into account the fact that in some Italian regions region-specific recovery plans, called "*Piani di Rientro*", have been implemented since 2007 in order to recover from the budget deficit related to health care expenditures (although measuring the effect of being included in such plans is beyond the scope of the paper). Although part of the literature agrees on the fact that being included in such plans helps to contained costs (Atella et al., 2019), the consequences in terms of health outcomes are less clear (see Arcà et al. (2020); Depalo (2019) for an estimation of the causal effects on health-related outcomes of recovery plans and Bordignon et al. (2020) for an evaluation of the recovery plans in terms of cost containment and safeguarding of an acceptable provision of health care services)[8]. A dummy variable is therefore included; 1 if the hospital is located in a region included in the recovery plan (*Recovery Plans*), and 0 otherwise.

A time dummy (*Time)* has also been included, taking the value of 1 if the hospital operates in year 2016 and 0 otherwise, to capture two different effects: (i) a change in technology over time when it is included in the production function, and (ii) a change in inefficiency over time when it is included in the variance of inefficiency term. Finally, a macro-area dummy has also been included to control for geographical area effects (*North*) taking the value of 1 in case the hospital is located in a region in the North of Italy, and 0 otherwise (Centre-South as reference group). Table 1 contains the descriptive statistics of the variables used in the production set. Table 2 specifies the outputs, inputs and the exogenous factor combinations in the empirical models. Hospitals in the southern regions have, on average, a lower number of personnel (both physicians and nurses) and beds available than those in the northern regions. Hospitals located in northern regions also have, on average, a higher number of discharged patients and emergency room treatments, as well as a higher number of inpatient days, compared to the hospitals in central and southern regions. See Figures 1 and 2 for a graphical representation of the inputs and outputs at regional level, respectively.

[Tables 1 and 2 around here]
[Figures 1 and 2 around here]

[8] Plans were signed in February 2007. To date, three waves of Piani di Rientro have been concluded. The first round of plans formally ended in 2009; afterwards, regions were allowed to sign new plans over the periods of 2010–2012 and 2013–2015. Ten regions underwent the program: Lazio was the first in February 2007; Abruzzo, Campania, Liguria, Molise and Sardegna joined the plan in March of the same year; Sicilia joined the plan in July of the same year. Of these regions, Liguria met requirements at the end of the first round (in 2010 instead of 2009) and left the program, whereas all of the other regions signed a new plan for 2010–12. For the second round, Calabria also signed a plan in December 2009 and Piemonte and Puglia signed a plan in 2010.

3.3 Composite index of efficiency: Benefit of Doubt Approach

Hospitals exhibit a wide variation in the quality of the product and its dimensionality which is particularly relevant on the output sides. To control for these types of differences, we construct a composite index consisting of the three output variables described above. Our main aim here is to avoid common subjectivity on the weight selection by proposing an endogenous weighting mechanism. Variables in which hospitals have a comparative advantage are more heavily weighted than variables in which hospitals have a lower comparative advantage, or even a comparative disadvantage. Since the strengths of hospitals differ, the weights on the performances should differ as well. For example, hospital X may perform relatively poorly with regard to the number of discharged patients. Therefore, in an endogenous weighting, the output 'number of discharged patients' will be assigned a lower weight in the weighting scheme. In contrast, outputs where the hospitals perform relatively well, for instance, the number of emergency room treatments, will obtain a higher weight. In a similar model the weights are observation-specific which contrasts with previous literature and practices. The idea corresponds to the benefit-of-doubt (BoD) model, a concept that was first developed by (Melyn and Moesen, 1991)[9]. Using BoD, each hospital gains its own weights that maximize (or minimize) the impact of the criteria in which the hospital performs relatively well (or poorly) compared to others[10]. In this paper, the BoD scores are used as composite output to measure the efficiency of hospitals.

4 Results

This section is divided into two sub-sections. First, we examine the results of the hospitals' metafrontier production function based on a stochastic frontier framework (§4.1). The results of the analysis of the inequality in hospital efficiency are then presented and discussed. (§4.2).

4.1 The hospitals' metafrontier production function

It is important to verify whether the hospitals operating in 2007 and 2016 share the same technology. Indeed, if the hospital data are truly generated from a single production frontier, then they should adopt the same underlining technology and therefore we are not justified in estimating the metafrontier production function. Following the approach suggested by Huang et al. (2014), we apply the likelihood ratio test for the null hypothesis that the production frontiers are the same for the two groups of hospitals (those operating in 2007 and 2016) and find that the null hypothesis is rejected supporting the idea that the sample

[9]See De Witte and Rogge (2011) and De Witte and Hudrlikova (2013) for an application of this method to higher education.

[10]Therefore, for each hospital, the BoD procedure searches for weights that maximize the impact of the strengths and minimize the influence of the relative weaknesses. This means that in absence of any other detailed information on the true weights, the BoD procedure assumes that representative weights can be inferred from looking at the relative strengths and weaknesses.

hospitals are operating, over a distance of almost a decade, using heterogeneous technologies. Therefore, the existence of a potential production technology gap justifies the estimation of the metafrontier production function in hospital performance/efficiency.

Table 3 reports the hospitals' stochastic frontier estimates. More specifically, Columns 1 and 2 report the estimates of the hospital group-specific stochastic frontiers for both years 2007 and 2016, respectively. The ratio of the group-specific production frontier to the metafrontier is reported in Column 3. The coefficients show that all the input variables have a positive and statistically significant effect on the outcomes of the hospitals (BoD composite index of efficiency). When considering the explanatory factors included in the analysis, our findings show that the variables used to control for the different competitive environments in which hospitals are located in have an important role in describing the variance of the inefficiency term. More specifically, being located in a region which is included in the recovery plan is negatively correlated with the technical level of inefficiency. This evidence suggests that being included in such plans not only helps to contain costs, but also seems to have positive consequences on the efficiency of the hospitals. This result corroborate the evidence of (Bordignon et al., 2020; Di Novi et al., 2019). Private hospitals outperform public hospitals. Finally, operating in more economically developed areas (North area of the country) is associated, on average, with higher efficiency. Given that there is a gap in economic development between northern and southern Italy, this result raises serious social issues under the equity profile. Indeed, all else equal, hospitals that operate in southern Italy are required to provide extra effort to produce the same level of output.

[Table 3 around here]

Table 4 reports the summary statistics of various efficiency scores, at regional level, for the two groups of regions (in 2007 and 2016)[11]. See, instead, Figure 3 for a graphical representation of the hospitals' efficiency scores at regional level. The average group-specific TE scores show a TE = 0.7904 for the hospitals in year 2007 and a TE = 0.7962 for the hospitals in year 2016. More specifically, almost all regions in 2016 (with the exception of Lazio, Puglia, Sardegna, Sicilia and Toscana) seem to be more technically efficient with respect to their own peer group in 2007. Furthermore, the estimates show that hospitals operating in 2016 seem to be highly more efficient in adopting the best available hospital-operating technology as measured in the technology gap ratio (TGR). The regions in 2016 has an average TGR of almost 1 versus an average TGR of 0.9753 for the same regions in 2007. In all, the hospitals in 2016 are more technically efficient with regard to the whole period as measured by the metafrontier technical efficiency (MTE). Indeed, the hospitals operating in 2016 have an average MTE of 0.7961 whereas the same hospitals in 2007 have an average MTE of 0.7737. While most of the regions in 2016 are found to outperform those in 2007 in terms of both TGR and TE measures, on average the TGR scores play a more important role in the determination of the ranking in MTE, suggesting that sources of inefficiency for hospitals operating in 2007 come especially from the technology used rather than managerial inefficiency. An interesting heterogeneity, however, can be seen

[11]The efficiency scores are obtained using data at individual hospital level and then summed up at regional level. The individual hospital efficiency scores are available on request.

when single regions are taken into account. Indeed, the TE scores play a more important role in the determination of the lowering (or not notable increasing) MTE ranking in 2016 with respect to 2007 for Lazio, Puglia, Sardegna, Sicilia and Toscana, suggesting that the primary source of inefficiency come from (lower) managerial efficiency rather than the technology undertaken. On the other hand, the TE scores play a more important role in the determination of the ranking in MTE for Emilia-Romagna, Friuli-Venezia Giulia, Piemonte, Trentino (P.A. Bolzano and P.A. Trento) and Veneto, suggesting that the primary source of efficiency in 2016 comes from (higher) managerial efficiency rather than the technology undertaken (that remain quite constant, although very high). Finally, although Basilicata, Calabria, Marche and Umbria in year 2016 outperform year 2007, the TGR scores play a more important role in determining the ranking in MTE, suggesting that for hospitals located in those regions the main source of efficiency come especially from the tehcnology undertaken rather than managerial efficiency. The opposite is true, insted, for Molise for which the main source of efficiency for hospitals operating in 2016 seems to come from managerial efficiency rather that the technology used.

[Table 4 around here]
[Figure 3 around here]

4.2 Rising Inequality in Hospital Efficiencies

In order to analyze the distribution over time of the 'more efficient and 'less efficient' hospitals, we divide the rank distribution of the hospitals' scores obtained into 5 percentiles to estimate the metafrontier production function. The graphical representation of the rank distribution is represented in Figure 4 (the blue, brown, green, orange and red lines illustrate, for each region and for years 2007 and 2016, the share of hospitals that falls in the 20^{th}, 40^{th}, 60^{th}, 80^{th} and 100^{th} rank percentile) and shows a clear and persistent North-South gap in the efficiency performances of hospitals. Indeed, in all the northern regions (Piemonte, Valle d'Aosta, Liguria, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia-Romagna) the hospitals' efficiency scores reached the highest $61^{th} - 80^{th}$ and $81^{th} - 100^{th}$ percentiles. The gap between the central-northern and southern regions did not change substantially between 2007 and 2016. An additional clear pattern is that none of the southern hospitals reach the highest percentile both in 2007 and 2016. More specifically, in the southern regions and in the two periods analyzed, the distribution of efficiency never reaches the highest percentiles in Basilicata, Calabria and Sardegna. These findings corroborate the results of previous literature, highlighting that in the last decades no process of convergence between the southern regions and those in the north has been observed (Lagravinese et al., 2019). The neglect inefficiencies are still evident between the two macro areas (north-south) and the best hospital in the south never reaches the results of the northern hospitals. This result may explain how health mobility between northern and southern regions has increased in recent years, posing serious problems of inequality due to the fact only people with higher incomes can afford to be treated outside their own region (Balia et al., 2018, 2020).

[Figure 4 around here]

The rank distribution can then be further decomposed in order to estimate the variability between and within regions according to equation (10). To this purpose, Table 5 reports the Theil index for hospital' performances, with two components: the between regions (estimated within 20 regions); and the within regions. Furthermore, to better understand the gap between the northern and southern regions, we have aggregated the efficiency scores in the two macro-areas.

Table 5 shows that between 2007 and 2016, the inequality in terms of efficiency between the areas of the country increased from 0.022 to 0.024. This result suggests that the differences between areas of the country have remained almost unchanged. Much of this inequality is determined by between inequality (around 63% of the total). In both years 2007 and 2016, the between inequality increased from 0.014 to 0.015 and the within inequality slightly increased from 0.0078 to 0.0095.

[Table 5 around here]

Additionally, we also calculate the Theil index for each region to further examine how the within inequality has changed in the single regions. These results, summarized in Table 6, show that in general, as was to be expected, inequality in the regions is not as high. This is explained by the fact that by now the regions have outlined the distribution of the service on the local territory where all the hospitals follow guidelines and homogeneous protocols in the regional territory. However, some differences can be seen. In the central-northern regions (net of the regions of Umbria and especially Lazio), it is generally observed that the differences in the same region are minimal with values very close to zero, while the differences are greater among the hospitals in the southern regions. Between 2007 and 2016, an increase in the within inequality occurred especially in Basilicata, Calabria and Sardegna. In the southern regions, therefore, differences persist even in the same region.

[Table 6 around here]

5 Concluding remarks and policy implications

5.1 Conclusion

This paper investigates the efficiency of Italian hospitals and how their performances have changed over the period 2007-2016. We apply the BoD approach to determine a composite index that considers the multi-dimensionality of the hospital outcome to be used as main output in a metafrontier production function based on a stochastic frontier framework. This procedure disentangles the group-specific frontiers and the metafrontier, further decomposing the efficiency scores of various groups of hospitals into technical efficiency scores and technology gaps. The main findings show that almost all regions in 2016 (with some exceptions) seem to be more technically efficient than their own peer group in 2007, also suggesting that, on average, the sources of inefficiency for hospitals operating in 2007 come especially from the technology used rather than managerial inefficiency. However, more heterogeneity is found when looking at the single regions. Indeed, managerial efficiency rather that the efficiency in adopting the best available technology seems to be more important (or not important) in determining the lowering (increasing) in the metafrontier technical efficiency ranking, especially for hospitals located in southern regions. Furthermore, with a closer look at the distribution of the efficiency scores across time, the empirical evidence shows a clear and persistent North-South gap in the efficiency performances of hospitals that did not change substantially between 2007 and 2016. Finally, when we further decomposed the rank distribution in order to estimate the variability between and within regions, the results show an increase in the inequality in terms of efficiency between the areas of the country mostly determined by between region inequality. An increase in within region inequality is also found, especially for the southern regions.

5.2 Policy implications

Several implications can also be derived from our analysis.

First, the findings highlight the still unresolved social-economic dualism between the northern and southern regions of the country. Indeed, a persistent territorial divide in the regional health care in Italy has been seen to be, at least partially, the possible cause of a large heterogeneity of mortality rates among regions (Arcà et al., 2020; Lagravinese et al., 2019). We find that the gap between the central-northern and southern regions not only did not change substantially between 2007 and 2016, but also that none of the central-southern hospitals reach the highest percentile in both periods, confirming that in the last decades no process of convergence between the southern regions and those in the north has been observed. Although, there is evidence of the general positive effect of decentralization on health performance in Italy (Atella et al., 2019; Bordignon et al., 2020; Di Novi et al., 2019) our study, along with some recent literature (Arcà et al., 2020; Depalo, 2019; Lagravinese et al., 2019) provides evidence that such improvements may not involve all the health dimensions and all the regions, and, more importantly, may not solve, even partially, the increasing gap between northern and southern regions. The decentralization process therefore does not seem to have helped to bridge the gap between hospitals in the north and those in the south. Indeed, the differences have also (albeit slightly) worsened over the years. In the next few years, also in light of the critical issues on regional organization revealed by the recent pandemic due to the COVID-19 virus, national policies will have to be implemented to bridge the infrastructural and economic gap in the southern regions. At the moment, with such a strongly dual country, full completion of the decentralized design and equality of opportunity of the health system is seriously jeopardized.

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Tables and Figures

Table 1: Descriptive statistics by geographical areas

	North-West	North-East	Centre	South	Italy
Inpatient days	91237.74	122713.24	82090.06	61708.61	83281.79
	(75356.82)	(114511.85)	(100979.22)	(66689.68)	(90703.36)
Discharged patients	987.01	986.72	776.88	644.70	799.84
	(1045.32)	(1556.95)	(986.64)	(760.09)	(1060.71)
Emergency room treatments	1520.97	1627.07	1222.27	963.50	1247.37
	(2490.24)	(4317.33)	(1959.88)	(1598.89)	(2549.33)
Physicians	181.75	214.43	189.52	152.93	178.82
	(147.46)	(198.03)	(221.03)	(156.71)	(183.55)
Nurses	376.86	589.51	418.73	324.65	407.18
	(325.51)	(537.20)	(463.49)	(311.18)	(416.43)
Other	406.94	497.62	309.70	222.41	327.02
	(338.22)	(463.43)	(428.67)	(240.64)	(374.12)
Beds	37.22	24.87	24.89	18.52	24.50
	(48.92)	(29.71)	(39.90)	(20.66)	(34.43)
Public	0.51	0.89	0.84	0.92	0.83
	(0.50)	(0.31)	(0.37)	(0.27)	(0.38)
Private	0.49	0.11	0.16	0.08	0.17
	(0.50)	(0.31)	(0.37)	(0.27)	(0.38)
Recovery plans	0.50	0.00	0.48	0.87	0.54
	(0.50)	(0.00)	(0.50)	(0.34)	(0.50)
Observations	134	148	216	308	806

Note: authors' elaboration.

Table 2: Estimating hospitals' efficiency – specification of outputs and inputs and exogenous factors

Variables	Definition
Inputs	
Physicians	# of physicians
Nurses	# of nurses
Other	# of other personnel
Beds	# of available beds
Outputs	
Discharged patients	# of discharged patients
Inpatient days	# of inpatient days
Emergency room treatments	# of emergency room treatments
Explaining the inefficiency	
Private	Dummy variable taking the value of 1 if the hospital has a private or accredited private health care ownership, and 0 otherwise
Recovery plans	Dummy variable taking the value of 1 if the hospital is located in a region included in the recovery plan, and 0 otherwise
North	Dummy variable taking the value of 1 if the hospital is located in a region located in the North, and 0 otherwise
Time	Dummy variable taking the value of 1 if the year is 2016, and 0 otherwise

Note: authors' elaboration.

Table 3: The hospital group stochastic frontier estimates

Y=Output BOD	(1) 1st step: Year 2007	(2) 1st step Year 2016	(3) 2nd step
	TE	TE	TGR
ln(Physicians)	0.286***	0.316***	0.272***
	(0.0874)	(0.0729)	(0.0178)
ln(Nurses)	0.423***	0.377***	0.436***
	(0.104)	(0.0788)	(0.0154)
ln(Beds)	0.0716***	0.0894***	0.0767***
	(0.0189)	(0.0171)	(0.00439)
ln(Physicians)^2	0.200**	-0.243*	0.0566
	(0.0944)	(0.146)	(0.130)
ln(Nurses)^2	-0.0424	-0.245	-0.0814
	(0.156)	(0.166)	(0.0585)
ln(Beds)^2	0.0470**	0.0382**	0.0460***
	(0.0218)	(0.0183)	(0.00428)
ln(Physicians)*ln(Nurses)	0.308	0.843***	0.442***
	(0.222)	(0.302)	(0.150)
ln(Physicians)*ln(Beds)	-0.0719	-0.244**	-0.132**
	(0.114)	(0.0999)	(0.0553)
ln(Nurses)*ln(Beds)	-0.154	0.139	0.00367
	(0.0963)	(0.0911)	(0.0450)
North (ref. group: centre-south)	-0.204*	0.00495	-0.0301*
	(0.113)	(0.0638)	(0.0171)
Time (ref. group: 2016)			-0.0917***
			(0.0172)
Constant	0.344***	0.321***	0.411***
	(0.0700)	(0.0499)	(0.0166)
Variance of inefficiency component			
Recovery plans	-2.518	-0.812**	-2.896**
	(1.743)	(0.378)	(1.339)
Private (ref. group: public)	-1.389***	-0.912***	-4.491***
	(0.265)	(0.217)	(0.809)
North (ref. group: centre-south)	-5.104*	-1.307**	-6.224*
	(2.709)	(0.540)	(3.426)
Time (ref. group: 2016)			-0.0641
			(0.698)
Variance of stochastic component			
Constant	-1.903***	-3.049***	-5.927***
	(0.139)	(0.256)	(0.325)
Observations	403	403	806

Note: Standard errors, clustered at regional level, in brackets; * p<0.10, ** p<0.05, *** p<0.01

Table 4: The estimates of the hospitals' metafrontier

	Year 2007			Year 2016			Overall		
Regions	TE	TGR	MTE	TE	TGR	MTE	TE	TGR	MTE
Abruzzo	0.6990	0.9678	0.6766	0.7243	0.9999	0.7243	0.7117	0.9839	0.7004
Basilicata	0.6725	0.9526	0.6410	0.6836	0.9996	0.6834	0.6781	0.9761	0.6622
Calabria	0.5986	0.9673	0.5788	0.6173	0.9999	0.6173	0.6080	0.9836	0.5981
Campania	0.6945	0.9682	0.6734	0.7250	0.9999	0.7250	0.7097	0.9841	0.6992
Emilia Romagna	0.9040	1.0000	0.9040	0.9599	1.0000	0.9599	0.9326	1.0000	0.9326
Friuli Venezia Giulia	0.8757	1.0000	0.8757	0.9521	1.0000	0.9521	0.9139	1.0000	0.9139
Lazio	0.7800	0.9779	0.7643	0.7348	0.9999	0.7348	0.7574	0.9889	0.7495
Liguria	0.9629	1.0000	0.9629	0.9696	1.0000	0.9696	0.9662	1.0000	0.9662
Lombardia	0.9839	1.0000	0.9839	0.9854	1.0000	0.9854	0.9847	1.0000	0.9847
Marche	0.7371	0.9333	0.6889	0.7594	0.9996	0.7592	0.7483	0.9665	0.7240
Molise	0.7948	0.9730	0.7744	0.8602	0.9999	0.8602	0.8275	0.9865	0.8173
P.A. Bolzano	0.8919	1.0000	0.8919	0.9559	1.0000	0.9559	0.9239	1.0000	0.9239
P.A. Trento	0.9039	1.0000	0.9039	0.9602	1.0000	0.9602	0.9321	1.0000	0.9321
Piemonte	0.9464	1.0000	0.9464	0.9796	1.0000	0.9796	0.9630	1.0000	0.9630
Puglia	0.7645	0.9715	0.7435	0.7553	0.9999	0.7553	0.7599	0.9857	0.7494
Sardegna	0.6776	0.9666	0.6548	0.5729	0.9996	0.5727	0.6252	0.9831	0.6137
Sicilia	0.9049	0.9892	0.8953	0.8938	0.9999	0.8938	0.8994	0.9946	0.8945
Toscana	0.6722	0.9341	0.6280	0.6634	0.9996	0.6632	0.6678	0.9669	0.6456
Umbria	0.6602	0.9155	0.6088	0.6953	0.9996	0.6951	0.6777	0.9576	0.6519
Veneto	0.9232	1.0000	0.9232	0.9656	1.0000	0.9656	0.9444	1.0000	0.9444
Total	0.7904	0.9753	0.7737	0.7962	0.9999	0.7961	0.7933	0.9876	0.7849

Note: Standard errors, clustered at regional level, in brackets; * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Valle d'Aosta is excluded having only one hospitals observation.

Table 5: Theil index: total, between and within inequality

Year	Total	Between Inequality	Within Inequality
2007	0.0220	0.0142	0.0078
2016	0.0245	0.0150	0.0095

Note: authors' elaboration.

Table 6: Theil Index Within inequality by regions

Regions	Within Inequality Year 2007	Within Inequality Year 2016
Abruzzo	0.004946	0.010415
Basilicata	0.007241	0.015273
Calabria	0.00954	0.027661
Campania	0.01993	0.01463
Emilia Romagna	0.000023	0.000002
Friuli VG	0.000394	0.000015
Lazio	0.020309	0.022959
Liguria	0.000357	0.00011
Lombardia	0.000094	0.00001
Marche	0.003231	0.001475
Molise	0.006215	0.001165
P.A Bolzano	0.000068	0.000003
P.A Trento	0.00062	0.000054
Piemonte	0.000098	0.000007
Puglia	0.011078	0.007498
Sardegna	0.008366	0.036281
Sicilia	0.002794	0.000399
Toscana	0.00996	0.012748
Umbria	0.022194	0.019508
Veneto	0.000679	0.000064

Note: authors' elaboration. Valle d'Aosta is excluded having only one hospitals observation.

Figure 1: Descriptive statistics: Inputs (geographical variation)

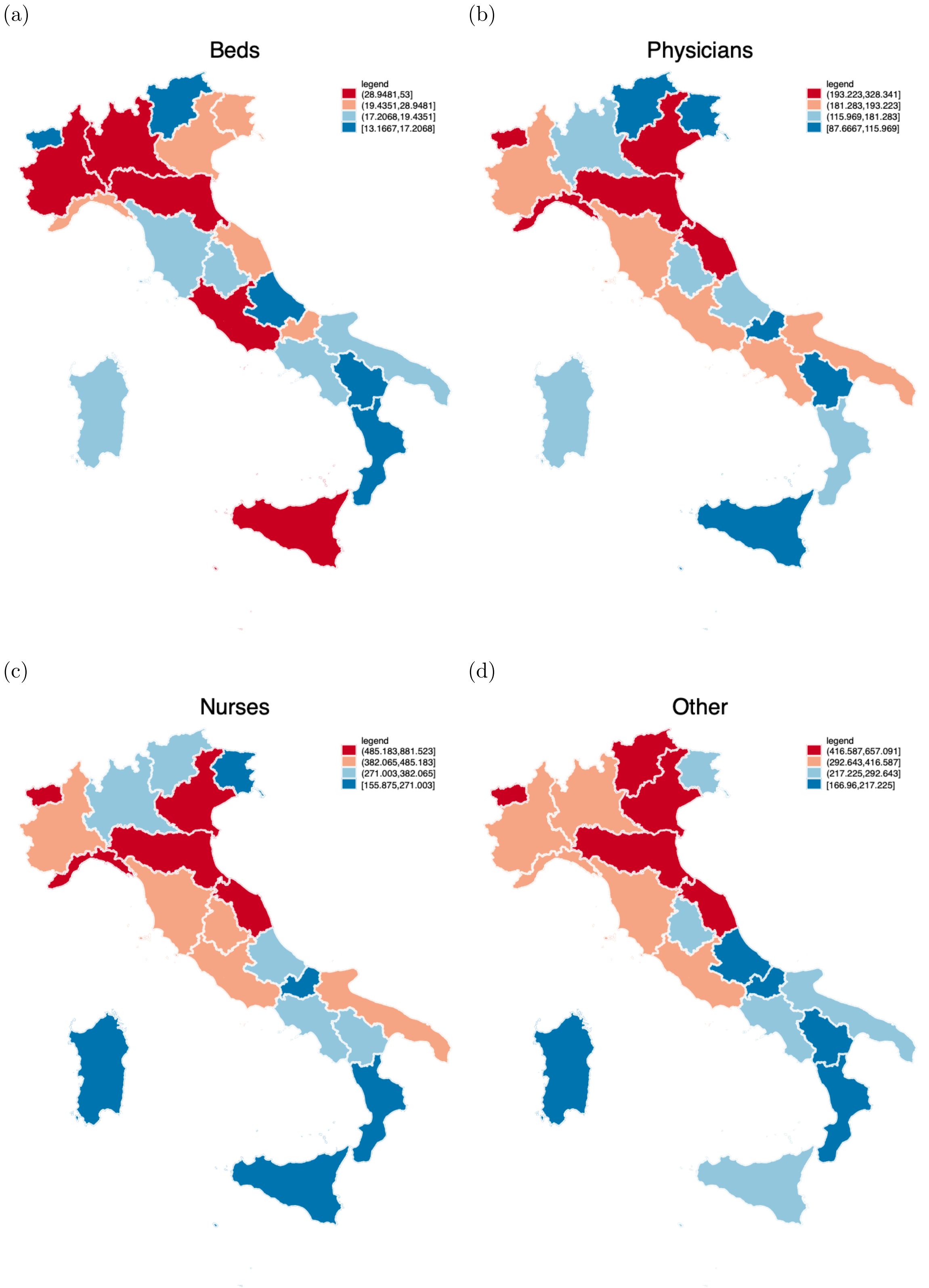

Figure 2: Descriptive statistics: Outputs (geographical variation)

(a) (b) (c)

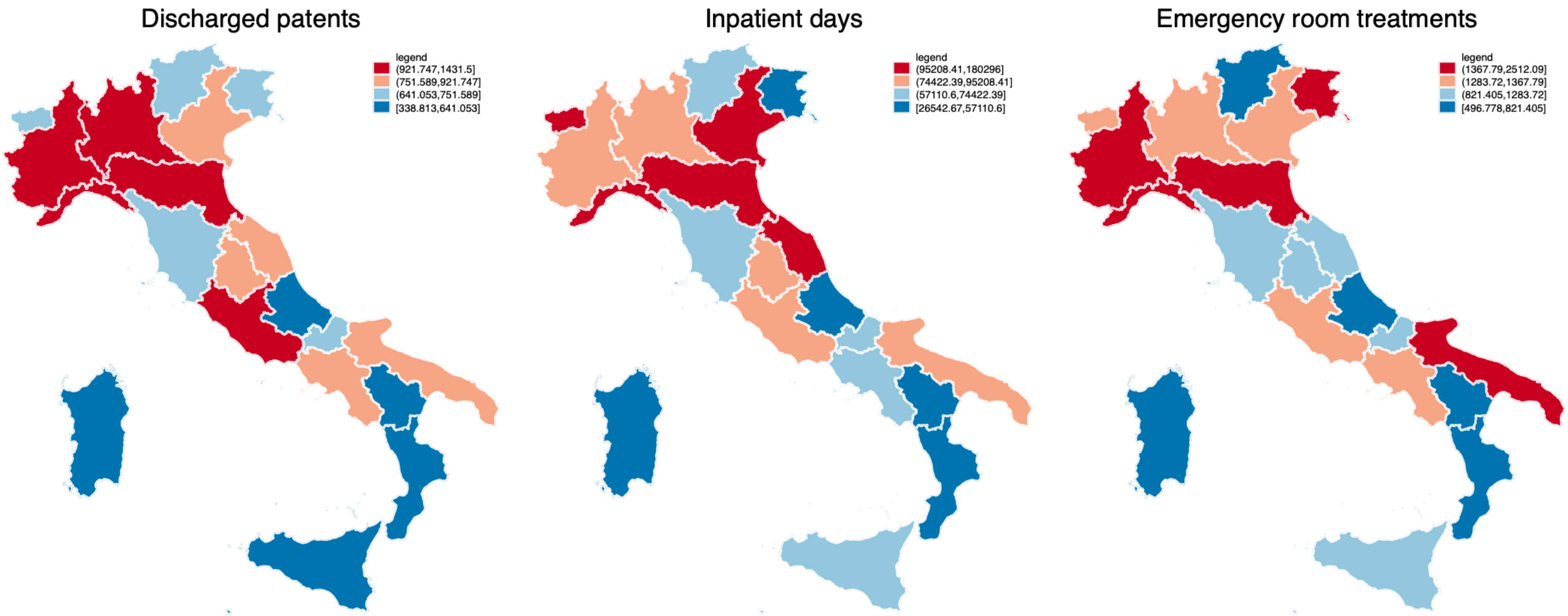

Figure 3: Hospitals' efficiency scores (geographical variation)

(a) (b) (c)

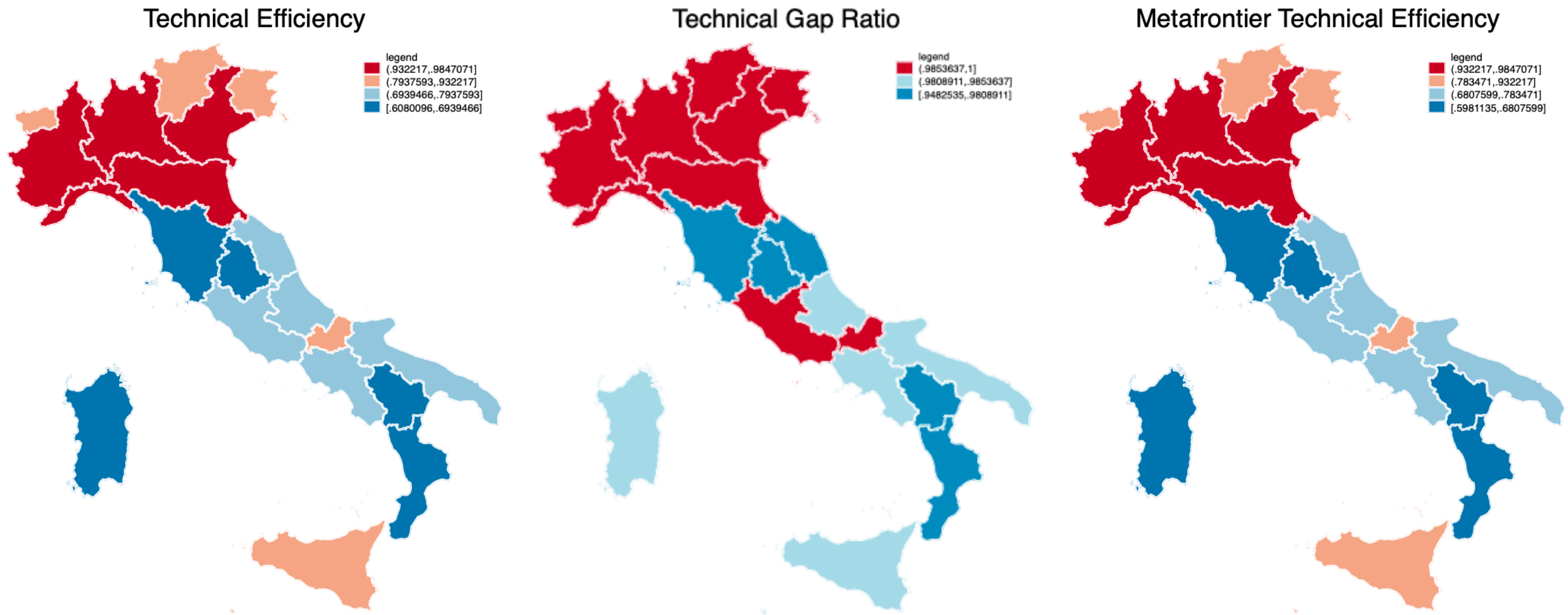

Figure 4: Rank distribution of the hospitals' efficiency scores at regional level for years 2007 and 2016