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Potential efficiency gains and expenditure savings in the Italian Regional Healthcare Systems

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Abstract
The paper aims to analyse the extent to which the adoption of best practice policies could improve the efficiency of Italian Regional Healthcare Systems (RHSs) and reduce public healthcare expenditures. By means of a stochastic frontier model we estimate the RHSs' technical inefficiency and its determinants using a panel data of 16 regions over the period 2010-2016. We use the Essential Levels of Care (LEA) scores computed by the Ministry of Health as a proxy for the RHSs' output and public healthcare expenditure as the main input. The level of inefficiency is a function of a set of variables summarising the organisational arrangements implemented by RHS policymakers. The results allow us to identify the best-practice policy, defined as the set of observable organisational arrangements that maximises aggregate efficiency. Adoption of the best-practice policy by all RHSs leads to potential efficiency gains of 1.5 per cent on average (from 93.4 per cent to 94.9 per cent) and to potential healthcare expenditure savings of 1.8 billion euro in 2016 (1.77 per cent of current expenditures).

Keywords
Healthcare expenditure, regional healthcare systems, efficiency, LEA scores

JEL Codes
H51, H75, I18, R50

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1. Introduction

With the growing importance of health-related spending worldwide, many efforts to estimate the technical efficiency of healthcare systems (Evans *et al.*, 2000; Hollingsworth, 2008; Hussey *et al.*, 2009; Maniadakis *et al.*, 2009; Tandon *et al.*, 2001; WHO, 2000) have been made. Yet the vast literature on this topic rarely provides policymakers with precise recommendations about policy adoption intended to increase efficiency (Gearhart, 2016; Gravelle *et al.*, 2003; Greene, 2004; Hollingsworth, 2003; Hollingsworth and Wildman, 2003; Kumbhakar, 2010; Street, 2003). In fact, most studies devote little attention to identifying the determinants of inefficiency in healthcare systems (Asandului *et al.*, 2014; Bonasia *et al.*, 2019; Häkkinen *et al.*, 2013; Heijink, 2013; Joumard *et al.*, 2010; Kujawska, 2015; Kumbhakar, 2010; Medeiros and Schwierz, 2015; Papanicolas and Smith, 2013; Prachitha and Shanmugam, 2012; Retzlaff-Roberts *et al.*, 2004). Further, even when the causes of inefficiency are identified, the most appropriate healthcare policy response is not specified and, therefore, no indications of the maximum level of efficiency attainable and the consequent possible expenditure savings are given.

The present paper focuses on the potential expenditure savings achievable by the Italian Regional Healthcare Systems (RHSs), the organisations responsible for delivering public healthcare services in Italy. The analysis is carried out by estimating the technical efficiency of the RHSs and the impact of best-practice policies on their expenditures.

To estimate the Italian RHSs' technical efficiency, we use the stochastic frontier model proposed by Battese and Coelli (1995). In this context, the estimated stochastic production function represents the ability of RHSs policymakers to produce the composite output indicator, the *Essential Levels of Care* (LEA – *Livelli Essenziali di Assistenza*) score using public health expenditure data. The LEA score is computed annually by the Italian Health Ministry to monitor the RHSs' activities. We hypothesise that the production frontier also depends on a vector of exogenous environmental variables that represent regional characteristics. The degree of technical inefficiency is a function of a set of variables that summarises the organisational arrangements implemented by RHSs and which is assumed to be fully controllable by policymakers. We define technical efficiency in terms of the standard Farrell output-orientated measure, which indicates the increase in output obtainable without requiring additional inputs (Coelli *et al.*, 2005). The estimates are based on a balanced panel of 112 observations of 16 RHSs over the time period from 2010 to 2016.

The estimates made allow us to evaluate how and to what degree RHSs' inefficiency and healthcare expenditures could reduce with the implementation of a best-practice policy. A best-practice policy is defined as the set of values of variables controlled by policymakers that, if adopted by all RHSs, maximises the average aggregate efficiency. To ensure feasibility, we identify the best-practice policy among the organisational policies actually observed in our sample. The impact of the best-practice policy on RHSs expenditure is obtained using the inverse of the estimated production function.

The efficiency of healthcare provision has, for the most part, been examined with reference to the efficiency of the hospital sector. A sizeable literature on the efficiency of hospitals has developed both internationally (see reviews in Colombi *et al.* 2017; Chowdhury and Zelenyuk, 2016; Jiang and Andrews, 2020; Mastromarco *et al.*, 2019) and with reference to the Italian case (Barbetta *et al.*, 2007; Canta *et al.*, 2006; Colombi *et al.*, 2017; Daidone *et al.*, 2009). The results of these studies are, however, of limited use to our study because of their particular perspective. As far as organisational variables are concerned, the most influential determinant of hospital inefficiency seems to be ownership type (public, private non-profit and private for-profit hospitals) (Barbetta *et al.*, 2007; Colombi *et al.*, 2017; Daidone *et al.*, 2009; Mastromarco *et al.*, 2019). This aspect is less relevant if we consider a regional healthcare system in which public and private hospitals of various types coexist. The same consideration may apply to other determinants of hospital inefficiency, such as, for instance, the size of the hospital, the degree of specialisation, teaching status, and occupancy rate. In any case, the studies examined highlight only the marginal effect of each determinant of inefficiency on output or cost, without accounting the effects on costs of optimal and feasible best practices.

Of the papers addressing the measurement of healthcare production inefficiency, only a few focus on the determinants of healthcare systems' inefficiency and provide targeted recommendations for policymakers. Generally, these studies use a two-step methodology whereby efficiency scores are first computed using data envelopment analysis (DEA) and then regressed on a series of environmental and institutional determinants (Allin *et al.*, 2015; Allin *et al.*, 2016; De Cos and Moral-Benito, 2014; Hadad *et al.*, 2013; Sun *et al.*, 2017).

This two-step approach has, however, some statistical drawbacks that may undermine the validity of the results obtained. As Simar and Wilson (2007) explain, DEA efficiency estimates are serially correlated, rendering this standard approach to inference invalid.

The two-stage approach seems inappropriate even when a regression is used in the first stage. Wang and Schmidt (2002) identify two sources of bias in this approach: first, the initial regression is misspecified since it does not include the determinants of inefficiency among the covariates. Hence, the regression suffers from a problem of omitted variables. Second, the inefficiency scores estimated in the first stage are under-dispersed, so the second-step estimates are biased downwards. To overcome biases due to the presence of the outliers, Gearhart and Michieka (2018) and Mastromarco *et al.* (2019) use a conditional order-m estimation procedure instead of DEA in the first stage of the analysis.

With the stochastic frontier model proposed by Battese and Coelli (1995), it is possible to estimate the parameters of the stochastic frontier and those of the inefficiency determinants simultaneously. Ogloblin (2011) and Wranik (2012) apply this methodology in their analyses of national health system efficiency. Jiang and Andrews (2020) use a stochastic frontier model to estimate a stochastic input distance function and a cost frontier. They consider multiple outputs and estimate the effects on inefficiency levels of variables characterising the local population.

A research area relevant to our purposes deals with the efficiency of local health systems. While analyses in this field encounter the same theoretical and empirical problems as do assessments of national health systems, there is some consensus that subnational analyses are statistically more robust and powerful in providing policymakers useful information because of the greater homogeneity of the systems under investigation (Allin *et al.*, 2015; Felder and Tauchmann, 2013; Kathuria and Sankar, 2005; Mukherjee *et al.*, 2010; Purohit, 2016; Singh, 2013).

Despite the wide range of studies on determinants of inefficiency (e.g. Anselmi *et al.*, 2017; Kinfu, 2013; Puig and Ortún, 2004), only a few have examined the efficiency of Italy's Regional Healthcare Systems (RHSs). Pammolli *et al.* (2015) measure the RHSs' efficiency using an input-oriented DEA model based on two composite inputs and a single composite output; the model summarises variables that include the number of inpatients, inpatient days, interregional mobility and outpatient care. For their part, Falavigna and Ippoliti (2013) estimate the technical efficiency of the RHSs using an output-oriented DEA wherein the output measure is the number of extra-regional patients treated in a region, and the input variables consist in the population, the number of doctors, technicians and nurses, the number of beds for acute hospitalisations and incoming mobility. The authors regress the resulting inefficiencies scores over a set of variables among which are the case-mix and the ratio of the number of public beds to the total number of beds (private and public). Their results confirm greater inefficiency in southern Italian regions, especially in Sicily and Sardinia.

The inefficiency of the Italian regional health systems is also the focus of Piacenza and Turati (2014), who estimated the average spending inefficiency at 2.5-3 percentage points. A peculiarity of this study is its methodological approach, based as it is on the stochastic frontier estimation of an input requirement function whereby public health expenditure is assumed to depend on health outcome measures, private health expenditure, and other exogenous variables.

This paper now proceeds as follows. Section 2 describes the Italian health system. Section 3 presents the econometric model used to estimate the RHSs' technical inefficiency and the method used to simulate potential efficiency gains and potential healthcare expenditure savings. Section 4 describes the data, and section 5 discusses the results. Concluding remarks are made in section 6.

2. Health services in Italy

2.1 Institutional framework

The Italian National Health Service (NHS) is a universal scheme funded mainly from general taxation that provides all citizens with access to healthcare services. In recent decades, the NHS has experienced an intensive process of decentralisation and is now organised on three tiers of government: state, regional and local authorities (Council of European Municipalities and Regions, 2013; Ferré *et al.*, 2014; Turati, 2013). At the national level, the Ministry of Health (MoH) sets the health system's fundamental principles and goals and uses a weighted capitation formula to allocate national funds to regions. The national government also has the exclusive authority to define the Essential Levels of Care (LEA), the mandatory standards of health services that must be guaranteed throughout the country and provided free of charge or with some cost-sharing (Turati, 2013). Provision of the LEAs is ordered through three macro-areas: public health, community health medicine and primary care, and hospital care.

Fifteen of the 20 Italian regions are ordinary statute regions and five are special statute regions,[1] all of which share planning and financing responsibilities with the central government and are exclusively responsible for delivering public health and healthcare services through their RHSs. The activity of each RHS is based on public hospital enterprises (*Aziende Ospedaliere*) and local health authorities (LHAs – *Aziende Sanitarie Locali*), which have a certain degree of autonomy. In this paper, we consider each RHS as a single decision-making unit that, given an amount of resources, seeks to maximise the quantity and quality of its health services (Anselmi *et al.*, 2017; Kumbhakar, 2010).

2.2 The output of the Italian Regional Healthcare Systems

Since this paper seeks to estimate a frontier production function of Italian RHSs, the most important choices we make concern defining outputs and inputs of the production process and their measurement. The efficiency of subnational health systems is, similarly to the country level, usually estimated using outcome indicators (potential years of life lost, life expectancy, survival rate, mortality rates, etc.) as dependent variables (Allin *et al.*, 2016; Bonasia *et al.*, 2019; Felder and Tauchmann, 2013; Kathuria and Sankar, 2005; Piacenza and Turati, 2014). When the analysis concerns local health systems, however, it seems more appropriate to shift attention from outcome measures to output measures since local health systems are characterised by high spatial interdependence (Felder and Tauchmann, 2013) and because high interregional mobility of hospital patients and populations can characterise local systems.

In Italy, patient mobility is guaranteed by the principle of freedom of choice as to the place of care, which is enshrined in the national laws based on Article 32 of the Constitution. On average, 8.5 per cent of people leave their region of residence for purposes of hospitalisation (Ministry of Health,

[1] The Italian Constitution guarantees special-statute regions greater fiscal autonomy and legislative powers than ordinary statute regions receive.

2017a).[2] Interregional migration of the population is also a significant phenomenon in Italy, with large flows of people moving from one region to another in recent years, mainly for work reasons. In 2015, for instance, 313,288 persons, or 5.15 per thousand, migrated between regions (ISTAT, 2016).[3] Thus, the health status of the residents in each region is only partially attributable to locally-provided health services and largely depends on lifestyle factors, on socioeconomic conditions, and on the healthcare services of other regions and nations. Given the weak link between the resources used by each RHS and the health outcomes in its domain that is further weakened by a considerable time lag between RHSs' actions and their results in terms of health status, we base our analysis on the *outputs* of regional healthcare provision.

Healthcare is a multi-product process (Lagravinese et al., 2017). Researchers often simplify this problem by considering just one or a few outputs (Anselmi *et al.*, 2017; Mukherjee *et al.*, 2010; Sing, 2013). Other authors reduce the complexity of the process by summarising a large number of indicators in one, or a few representative variables using principal component analysis (Pääkkönen and Seppälä, 2014). Compared to the analyses that consider only one output indicator, this latter approach reduces the bias in estimates of the healthcare system's efficiency.

In Italy, the multiple activities the RHSs carry out are evaluated by means of a composite indicator, the LEA score, computed annually by the Ministry of Health (Turati, 2013; Signorelli *et al.*, 2020). Regions are required to provide some minimum levels of healthcare services which are defined by Ministerial decree. A permanent committee within the Ministry of Health analyses regional performance using a set of indicators, namely, the LEA grid. For 2016, the last year of our analysis period, the LEA grid consisted of 35 physical indicators, grouped into three macro-areas: prevention, outpatient and community care, and hospital care and emergency care.[4]

Each of these indicators compares an RHS's performance to the national standard and is scored on four levels, from a minimum of zero to a maximum of nine points. The total score computed for each region, the LEA score, is a weighted average of the indicators' scores, where the weight assigned to each indicator depends on its relevance in the grid.[5] The LEA score reflects the region's performance in delivering LEAs such that the LEA score for region r at time t is defined as:

$$LEA_{rt} = \sum_{i=1}^{35} f_i(y_{irt}) w_i,$$

where y_{irt} is a measure of the i-th output indicator, $f_i(\cdot)$ is the function that converts y_{irt} into a score (from 0 to 9), and w_i is the weight assigned to the i-th output indicator. Weights range from 0.1 to 2.5, and the LEA score can reach a maximum of 225. Function $f_i(\cdot)$ is a step function that assigns a score of 9 if an LEA target is completely achieved, scores of 6 and 3 if the target is not completely achieved, and a score of 0 for very low performance.

[2] In some regions, however, particularly the smallest and those in southern Italy, these percentages are much higher, reaching 30 per cent. Balia *et al.* (2017) suggest that local supply factors like hospital capacity and technology endowment, clinical specialisation and performance indicators are important drivers of patient mobility. Geography has a significant effect as well, and spatial proximity plays an important role in reinforcing interregional mobility patterns.

[3] This phenomenon is not uniform across the country: in 2015, Northeast regions had an inflow of 69,932 persons from other regions (6‰ of the population), whereas Northwest regions had an inflow of 93,222 persons (5.78‰). International migration also plays a part, as the national average immigration rate is of 4.6 per cent, with the highest rate (5.32‰) in Lombardy.

[4] The complete list of these indicators is published by the Ministry of Health (2017b). Indicators include vaccine coverage, screening extension, controls for animals, food safety, organisational and clinical appropriateness, home care, residential care activity, hospitalisation rates, and rates of medical access. A short description is available in the Expert Group on Health Systems Performance Assessment (2016), and some comments are available in Davoli *et al.* (2017).

[5] The LEA score differs from other Composite Measures of Healthcare Delivery used in the literature in that it considers the largest number of output variables and because output weights are defined by the national government.

The main statistics pertaining to the LEA scores of the 16 regions examined (15 ordinary statute regions and Sicily, a special statute region) for the period 2010-2016 are shown in Table 1.[6] These scores are the output variables used in the econometric analysis carried out in section 4. The LEA scores show a clear positive trend throughout the period from 2010 to 2016, with the mean score rising from 146.08 to 183.29.

Table 1 - LEA scores and public healthcare expenditure

Year	LEA scores *				Real per capita public healthcare expenditure (euro, 2015 prices) **			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
2010	146.08	40.64	73.70	208.05	1961.08	89.14	1860.05	2254.83
2011	164.02	31.09	109.95	215.25	1930.22	94.43	1808.46	2206.02
2012	169.24	26.51	117.00	210.00	1883.72	115.63	1741.24	2136.71
2013	173.51	26.41	134.00	214.00	1830.48	100.49	1683.69	2234.87
2014	180.11	22.58	137.00	217.00	1817.28	84.99	1686.97	2132.42
2015	177.94	31.28	106.00	212.00	1787.37	87.60	1652.33	2002.34
2016	183.29	26.49	124.00	209.00	1788.04	82.71	1645.95	2005.83

*Source: * Ministry of Health (2018) and previous editions. ** ISTAT (2019) and our elaborations.*

Notes: Data refers to the RHSs of the 15 Ordinary Statute Regions and Sicily. Weighted averages.

In our approach, unlike in those based on techniques involving a different endogenous weighting of the outputs for each DMU, we want to consider the preferences of the central government policymaker as explicitly incorporated in the definitions of the LEA scores. Consequentially, the estimated levels of efficiency are premised on central government policymakers' preferences about the set and the mix of output variables.

2.3 The main input: public health expenditure

As Greene (2004, p. 966) states, "Health expenditure is the most visible input to the healthcare process, and public health expenditure is a major component of healthcare policy." This view is widely accepted in the literature (Evans *et al.*, 2000; Kumbhakar, 2010; Tandon *et al.*, 2001). According to Allin *et al.*'s (2015) study on Canadian health regions, based on a qualitative analysis of stakeholders' perspectives, health expenditure is the correct proxy for input. Wranik (2012) uses healthcare expenditure as the sole production input; Kathuria and Sankar (2005) recognises that healthcare expenditure should be used as production input, though, lacking data, they did not utilise it.

In line with this approach, we deem public health expenditure to be the production input of the RHSs' production process. This choice is also influenced by the Italian institutional context; RHSs directly produce only part of the healthcare services delivered to the regional population, since a consistent share of services are produced by other public and private providers accredited by the NHS. Therefore, the amount of physical input, such as labour and capital, an RHS uses is related less to its overall production of healthcare than it is to the financial effort measured in public health expenditure.

[6] The remaining four regions are special-statute regions whose RHSs are not financed through the National Health Fund. The Ministry of Health did not begin to monitor their performance by means of the LEA scores until 2017.

Table 1 shows that the real per capita public healthcare expenditure[7] and LEA scores have an opposite trend: the former decreased by 8.8 per cent (from 1,961.08 to 1,788.04 euro) over the period, while the latter grew by 25.5 per cent (from 146.08 to 183.29), suggesting that efficiency could have increased over this interval.

3. The method of analysis

3.1 The stochastic frontier model

The Italian RHSs' technical efficiency is estimated using the stochastic frontier model proposed by Battese and Coelli (1995). This model, which is suitable for use with panel data, allows us to estimate the parameters of the stochastic production frontier, the parameters of variables influencing inefficiency, and the degree of technical inefficiency simultaneously.

We estimate a stochastic frontier production function in which technical efficiency represents the ability of RHS policymakers to convert public health expenditure (*E)* into *LEA* scores (L), the aggregate output indicator provided by the MoH. Following the approach of Coelli *et al*. (2005), we hypothesise that the production frontier depends, in addition to input E, on a vector of K other exogenous environmental variables $x = (x_1, x_2, \dots, x_k, \dots, x_K)$, which represent regional characteristics. We assume that inefficiency depends on a vector of M variables $z = (z_1, z_2, \dots, z_m, \dots, z_M)$ which summarise the organisational arrangements implemented by the RHSs. These variables are controllable by RHS policymakers and managers. Hence the econometric model is the following:

$$\ln L_{it} = \alpha + \beta \ln E_{it} + \sum_k \gamma_k \ln x_{kit} + v_{it} - u_{it} \tag{1}$$

$$v_{it} \sim N(0, \sigma_v^2) \tag{2}$$

$$u_{it} \sim N^+(\sum_m \delta_m \ln z_{mit}, \sigma_u^2)\ , \tag{3}$$

where $i = 1, \dots, N$ is the RHS, $t = 1, \dots, T$ is the time index, and v_{it} refers to the usual random errors (equation 2), assumed independently distributed of u_{it}. Finally, u_{it} refers to non-negative random variables that indicate the technical inefficiency and that depend on the policy variables z (equation 3).[8]

Estimating the stochastic frontier model represented by equations (1) - (3) allows us to obtain the expected values of inefficiency terms, $\hat{u}_{it} = E[u_{it}|v_{it} - u_{it}]$, and those of technical efficiency, $\widehat{TE}_{it} = [\exp u_{it}\, |v_{it} - u_{it}]$. As Battese and Coelli (1995) showed, these expected values depend on all the model's variables and parameters.

3.2 Potential efficiency gains and potential healthcare expenditure savings

The model allows us to assess the degree to which the healthcare system's efficiency could increase and healthcare expenditure be reduced if policymakers were to adopt a particular best-practice policy, given the existing technological and environmental context.

[7] Current values have been deflated using the regional implicit deflator of GDP (2015=1).

[8] Since public healthcare expenditure is almost completely determined by state funding and so is exogenous with respect to RHS decisions, we can assume that the u_{it} is uncorrelated with E_{it}.

Let z^* represent a best-practice policy, i.e. the particular set of values of controllable variables which, if feasible and implemented simultaneously by all RHSs, allow the attainment of some social goal defined at the national level (e.g., maximum aggregate efficiency or minimum variance of efficiency levels among regions). The adoption of the best-practice policy z^* leads to new expected values for the inefficiency term $\hat{u}_i^* = \Omega\left(L_i, E_i, x_i, z^*, \hat{\alpha}, \hat{\beta}, \hat{\gamma}, \hat{\delta}, \hat{\sigma}_u^2, \hat{\sigma}_v^2\right)$, technical efficiency $\widehat{TE}_i^*$, and the output level $\hat{L}_i^*$ for all RHSs.[9] The potential efficiency gains (PEG) achievable from a best-practice policy is then:

$$PEG_i = \widehat{TE}_i^* - \widehat{TE}_i \ . \tag{4}$$

Given the level of health expenditure, the resulting increase in the production of LEAs is equal to $\hat{L}_i^* - \hat{L}_i$, where $\hat{L}_i$ is the expected level of LEA in the initial condition.

The new expected inefficiency level, $\hat{u}_i^*$, can be used to compute the potential healthcare expenditure savings, a monetary measure of inefficiency for policy purposes that is defined as the savings an RHS could achieve if it produced the same expected output in a more efficient way.

Let $ER_i(\hat{L}_i, \hat{u}_i^*)$ be the minimum per capita public health expenditure requirement that allows the RHS to produce the same level of expected output $\hat{L}_i$ when it adopts the best-practice policy, i.e. when the inefficiency term is $\hat{u}_i^*$. The value of $ER_i(\hat{L}_i, \hat{u}_i^*)$ can be obtained by solving the estimated equation:

$$\ln \hat{L}_i = \hat{\alpha} + \hat{\beta} \ln E_i + x_i \hat{\gamma} - \hat{u}_i \ . \tag{5}$$

With respect to E_i and substituting the inefficiency term with $\hat{u}_i^*$:

$$ER_i(\hat{L}_i, \hat{u}_i^*) = \exp\left[\left(\ln \hat{L}_i - \hat{\alpha} - x_i \hat{\gamma} + \hat{u}_i^*\right) / \hat{\beta}\right] . \tag{6}$$

Equation (6) is an input requirement function, as defined by Diewert (1974), evaluated at $\hat{u}_i^*$. The difference between E_i and ER_i is the potential healthcare expenditure savings, PES_i:

$$PES_i = E_i - ER_i \ . \tag{7}$$

The potential expenditure savings are computed using the production function estimates of models (1) - (3), so they are coherent with those estimates. This is a substantially different approach to that of De Cos and Moral-Benito (2011), who propose a two-step method,[10] and also to that followed by Kumbhakar (2010) and Piacenza and Turati (2014), who compute the potential savings by directly estimating an input requirement function.

4. Data description

The model defined by equations (1) - (3) has been estimated with a balanced panel of 112 observations regarding 16 RHSs over the seven-year period from 2010 to 2016.[11] The number of observations is limited both by the unavailability of the LEA score prior to 2010 and the data for some variables being unavailable at the time of the analysis for the years after 2016. For four Italian regions – Valle d'Aosta, Trentino A.A., Friuli Venezia Giulia and Sardinia, which are special statute

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[9] Hereafter, for ease of notation, we omit the time subscript.

[10] In this case, the second stage was based on a regression with the healthcare outcome as the dependent variable and the health expenditure and the level of technical efficiency obtained in the first stage as covariates.

[11] The estimations were made using Stata (StataCorp, 2017).

regions – the LEA score was calculated from only 2017 onwards, and so these were excluded from the analysis. The main statistics concerning the raw values of the variables considered in the analysis are shown in Table 2. In the period 2010-2016, the overall mean of the LEA score (L) is 168.82, while the overall mean of the real public healthcare expenditure (E) is 1,872 euro per capita (yearly data are shown in Table 1).

The most important exogenous environmental variable (x in equation (1)) is the share of household healthcare expenditures in total healthcare expenditure (HHE), which ranges from a minimum of 14.97 per cent to a maximum of 28.78 per cent (Table 2). Household healthcare expenditure could influence RHS output because it is partially directed to the purchase of services provided by the public health system, which can bolster RHS revenues and return to scale. Moreover, some part of household healthcare expenditure is directed to private providers, which reduces the need for the public healthcare sector's intervention and increases the amount of resources available for institutional activities.

Among others, Levaggi and Turati (2010) discuss the issue of the dynamic interrelation of household and public healthcare expenditures, which can be understood as substitutes or complements depending on the relative importance of effects like topping up or opting out. However, in the institutional context considered here, public healthcare expenditure is certainly exogenous, since it is determined by the central government's budgetary constraints and allocation criteria among regions. On the other hand, in our panel data we do not observe high correlation between the two variables, at only 0.2373. This result is contrary to the idea that public and private healthcare spending are substitutes (for either the topping-up or the opting-out effect). The small positive correlation can be explained by allowing that private healthcare expenditure depends primarily (as the authors cited in the paper point out) on the level of per capita income. In our panel data, the correlation between GDP and private healthcare expenditure is about 84%. Moreover, we use the share of private expenditure in the total health expenditure. The even smaller and negative correlation (-0.1159) of this variable with public expenditure thus leads us to think that the endogeneity problem cannot be counted as critical.

Other exogenous environmental variables are demographic density and the natality rate.[12] Both variables show high variability in the sample, as density ranges from 56.79 to 429.08 inhabitants/km^2, and the natality rate varies from 6.3 to 10.0 live births per thousand inhabitants. A time trend is also included in the regression.

[12] The set of environmental variables initially considered was wider than that which appears in the full model. However, only those used in the full model were unrelated to the others. We selected variables in two steps. First, we checked the presence of multicollinearity (with the Stata command `collin`) and dropped all variables with a VIF value higher than 10 (i.e. employment rate, activity rate, old age rate, per capita real GDP). In the second step, we looked at the correlation matrix and excluded variables with correlations with other variables higher than 0.5 and with the lowest correlation with the dependent variable (i.e. population, unemployment rate, foreign citizen share, revenue from co-payments, revenue from goods and services, share of expenditure for administrative personnel).

Table 2 - Descriptive Statistics (*Number of observations: 112. Number of RHSs: 16. Years: 2010-2016).*

Variable	Source	Description	Mean	Std. Dev.	Min	Max
L	*A*	Essential levels of care (LEA scores)	168.82	30.03	73.70	217.00
E	*B*-9010§	Real per capita public healthcare expenditure (euro, 2015 prices)	1872.22	132.55	1645.95	2254.83
HHE	*B*-9023§	Share of household healthcare expenditure in total health expenditure %	22.55	3.10	14.97	28.78
DENS	*B*-0000§ and *C*	Demographic density of the region (inhabitants/km^2)	207.57	108.82	56.79	429.08
NAT	*B*-0190§	Natality rate (born alive per 1,000 inhabitants)	8.28	0.83	6.30	10.00
T		Time trend (*TT*=1 if *t*=2010)	4.00	2.01	1	7
EA	*B*-9023§	Share of public healthcare expenditure for services provided by private accredited providers in total public health expenditure %.	34.89	5.42	25.49	43.43
HO	*B*-7343§	Share of resident population hospitalized outside the region on total resident hospitalization %	11.09	6.08	3.64	26.70
PT	*C*	Share of expenditure for technical personnel in total public healthcare expenditure %	3.54	0.74	1.86	4.53
d_int	*D*	Dummy for regions with an integrated healthcare system (3 regions)	0.19	0.39	0.00	1.00
d_sep	*D*	Dummy for regions with a separated and quasi-separated healthcare system (4 regions)	0.25	0.43	0.00	1.00
DLHA	*C*	Average demographic size of Local Health Authorities (inhabitants)	517,963	334,088	221,182	1,562,439
POP	*B*	Resident population (annual average)	3,518,038	2,484,978	311,238	10,013,758
ACTIVE	*B*	Activity rate (%)	47.60	5.52	37.87	55.30
UNEMP	*B*	Unemployment rate (%)	11.76	4.97	4.90	23.42
EMPL	*B*	Employment rate (%)	42.22	6.82	30.35	51.46
OLDAGE	*B*	Old age rate (%)	164.75	30.599	97.6	248.14
FOREIGN	*B*	Share of resident foreign citizens (%)	7.05	3.374	2.06	12.06
GDPP	*B*	Real GDP per capita – (euro, 2015 prices)	25,485	6,640	16,051	37,897
RGSP	*B*	Revenue from goods and services (euro per capita, 2015 prices)	112.78	64.17	11.95	311.25
PA	*B*	Share of expenditure for administrative personnel in total public healthcare expenditure (%)	0.024	0.004	0.015	0.034
COPAYP	*B*	Revenue from co-payments (euro per capita, 2015 prices)	23.94	9.26	8.50	43.12

Source: A: Ministry of Health (2018), and previous editions. B: ISTAT (2019). C: ISTAT (2018). D: Mapelli (2012).

§: Health for All Italia - indicator number.

The choice of variables presupposed to influence inefficiency (z in equation (3)) is based on the Italian health system's institutional set-up. A feature that significantly differentiates Italian RHSs is the participation of private operators in health services provision. This feature may be central to determining the system's efficiency, but in which direction is unclear since regions with both high and low private provider participation rates have high LEA scores. This aspect is assessed by the share of public healthcare expenditure for services provided by private accredited operators (EA), including for items such as pharmaceuticals, general medical expenses, medical-specialist costs, and spending on private care facilities. The value of this share of expenditures ranges from a minimum of 25.49 per cent of total expenditures to a maximum of 43.43 per cent (Table 2).

Another aspect that can affect RHS efficiency is patients' interregional mobility. The fees applied by RHSs for health services provided to patients from other regions may differ from internal production costs and affect the system's efficiency. For this reason, the resident population hospitalised outside its region as a share of total resident hospitalisation (HO) is introduced among the determinants of inefficiency.

Since some labour costs could be relevant to the analysis because they are indicative of different approaches to health service production, we also consider the share of costs for technical staff (e.g., statisticians, sociologists, analysts, professional collaborators, social workers, technical assistants, programmers) in total public healthcare expenditure (PT) as a determinant of inefficiency. The technical staff is the production factor most affected by the rationalisation policies implemented by RHSs to reduce costs because often their roles are considered inessential to healthcare activities. However, preliminary analysis revealed a high positive correlation between *PT* and the LEA score (0.57) which leads us to believe that policies of containing technical staff costs may be counterproductive, since such employees are relevant to production purposes. Subsequent analyses aimed to test this hypothesis.

The role of private operators is assessed according to the classification of RHSs proposed by Mapelli (2012), who defines four institutional models (separated, quasi-separated, quasi-integrated and integrated) based on the number of hospital beds directly managed by the RHSs as a share of the total number of beds.[13] We evaluate how these institutional models affect efficiency by introducing four regional dummy variables. Since the separated model applies to only one region (Lombardy), we have grouped it with the regions representing the quasi-separated model (the dummy d_sep in Table 2) to prevent the corresponding dummy capturing regional effects rather than representing the separated model. The dummy for the quasi-integrated institutional model is embedded in the constant.

Finally, we introduce the average demographic size (DLHA) of the LHA comprising the RHS to assess the effect of the territorial subdivision decided by the regional policymakers (Di Novi *et al.*, 2018).

5. Results and discussion

5.1 Estimation of the stochastic production frontier

Table 3 reports the estimates for the full model and a more parsimonious specification, the latter obtained by eliminating the non-significant variables step by step. A likelihood-ratio test shows that the null hypothesis that the dropped variables' coefficients are jointly zero cannot be rejected (Table

[13] Mapelli (2012) defined the institutional model using the number of hospital beds directly managed by the RHSs as a share of the total number of beds: "separate" model with a share <1 per cent (Lombardy); "quasi-separated" model with a share of 20-40 per cent (Lazio, Campania, Calabria), "quasi-integrated" model with a share of 40-66 per cent (Piedmont, Liguria, Emilia-Romagna, Toscana, Umbria, Marche, Apulia, Basilicata, Sicilia) and "integrated" model with a share >66 per cent (Abruzzi, Molise, Veneto).

A.1 in the Appendix). The goodness of the parsimonious model is also confirmed by Akaike's and Schwarz's Bayesian information criteria, which are always lower for the parsimonious model. (See the AIC and BIC statistics reported in Table 3). Some additional tests (Table A.1 in the Appendix) confirm the validity of this specification.

Considering the parsimonious model, Table 3 shows that the elasticity of the LEA score with respect to per capita public health expenditure is 0.8213. Since the output-expenditure elasticity is less than one, it follows that the marginal and the average productivity of public expenditure are decreasing (Canta *et al.*, 2006). Moreover, the estimates confirm the hypothesis that the share of household healthcare expenditure positively influences public sector healthcare production across Italian regions (the coefficient of $\ln \mathrm{HHE}$ is 0.5201) and confirm the results of Del Vecchio et al. (2015a, 2015b, 2015c).

Table 3 - The stochastic production frontier estimate

Dependent variable: ln L	*Full model*		*Parsimonious model*	
	Coefficient	*P-value*	*Coefficient*	*P-value*
ln*E*: public healthcare expenditure	0.8432	0.0000***	0.8213	0.0000***
ln*HHE*: % of household health expenditure	0.5001	0.0000***	0.5201	0.0000***
ln*DENS*: demographic density	-0.0660	0.0023***	-0.0632	0.0011***
ln*NAT*: natality rate	0.0492	0.6952		
ln*T*: time trend	0.0506	0.0473**	0.0420	0.0065***
Constant	0.0550	0.9635	0.1231	0.9134
Inefficiency (u_{it})				
EA: services provided by private accredited providers †	0.0709	0.0445**	0.0713	0.0368**
PT: expenditure for technical personnel †	-0.1198	0.0022***	-0.1029	0.0026***
HO: hospitalized outside the region †	0.1781	0.0000***	0.1617	0.0000***
d_int: dummy for integrated model	-0.1844	0.0290**	-0.1626	0.0196**
d_sep: dummy for separated and quasi-separated model	-0.0328	0.5665		
DLHA: dimension of Local H.A. †	0.0364	0.1841		
T: time trend	-0.0776	0.0000***	-0.0760	0.0000***
Constant	0.3364	0.0000***	0.3227	0.0000***
Inverse logit of γ	2.6477	0.0000***	2.6733	0.0000***
$\ln \sigma^2$	-4.1154	0.0000***	-4.0933	0.0000***
σ^2	.016319		.01668	
γ	.933870		.93543	
Number of observations	112		112	
Wald χ^2	102.7449		117.157	
Prob>χ^2	0.00000		0.00000	
Log_likelihood	129.1066		127.9823	
AIC	-226.2132		-229.9646	
BIC	-182.7172		-194.6241	

† *standardized value (ratio to the mean). * p<0.1. ** p<0.05. *** p<0.01.*

Regarding the determinants of inefficiency (the z variables in equation (3)), Table 3 shows that the higher the share of public healthcare expenditure for services provided by private accredited suppliers (EA), the greater the inefficiency (+0.0713). This result is important in the Italian context, where the externalisation of health services' influence on efficiency is widely debated. This result confirms those of Falavigna and Ippoliti (2013) concerning Italy and of Mukherjee et al. (2010), which found local health departments in the US to be more efficient when they produce health services internally.

The estimated coefficient of the share of the hospitalised resident population hospitalised outside the region (HO) is positive and very significant (+0.1617). This confirms the well-known correlation between regional health system inefficiency and hospital emigration, a phenomenon that is particularly relevant in the southern regions of Italy (Censis, 2017; Gimbe, 2019). Notwithstanding patients' freedom of choice in the place of care, regions have some power in controlling outgoing patient flows and the central government incentivises regions to do so. By controlling hospital emigration, policymakers can avoid the duplication of some costs, i.e. the cost of external hospitalization and fixed internal costs, and thereby increase efficiency.

The analysis shows that RHSs with relatively high technical staff costs (PT) are characterised by relatively low inefficiency (-0.1029). As the wage rates of technical staff are established by national collective labour agreements and therefore homogeneous across regions, higher PT expenses can signal the greater presence of technical staff, who are essential to ensuring efficient delivery of health services. Therefore, this result indicates that efficiency declines when the activities carried out by technical staff are reduced or outsourced.

As for the roles played by the different institutional models in determining efficiency, only one of the two dummies considered is significant (*d_int*, integrated healthcare system). The coefficient is negative (-0.1542), indicating that adoption of the integrated model – as in Abruzzi, Molise and Veneto – is associated with a lower level of inefficiency. This result contributes to assessing which is the best institutional model among those proposed by Mapelli (2012). Adoption of the integrated model could improve the efficiency of RHSs since it allows greater control over hospital care costs and better quality of these services.

5.2 Potential efficiency gains and potential expenditures savings

Table 4 shows the predicted values of technical efficiency ($\widehat{TE}$) for each RHS. The mean value for 2016, the last year in our sample, is 93.4 per cent. The most efficient RHSs are those of Tuscany and Veneto, where $\widehat{TE}$ is greater than 98 per cent, and the least efficient are those of Campania and Molise, which score 78.5 per cent and 78.8 per cent, respectively. The ranking of the most efficient RHSs is in line with the results of the analyses of the Italian case discussed in Section 1.

Let us now see what potential efficiency gain (PEG) could be achieved if a best-practice policy were implemented (equation 4). We define the best-practice policy, z^*, as the set of values of the controllable variables (EA, PT, HO, d_int) that maximises overall technical efficiency should that policy be pursued simultaneously by all RHSs, while keeping the environmental variables at their observed value. To ensure that the policy is feasible, we chose the best-practice policy from policies actually observed in the RHSs in 2016. For each policy actually in place in the RHSs we computed the aggregate value of $\widehat{TE}^*$ (see Table A.2 in the Appendix), and found that the best-practice policy is that implemented in the Veneto RHS. This policy allows for an average PEG of 1.48 percentage points (from 93.4 per cent to 94.9 per cent) and for the maximisation of the aggregate output (LEA scores).[14]

Resulting PEGs differ significantly among the regions (Table 4), being twice the average in regions with low technical efficiency (close to 3.76 per cent in Calabria and to 4.53 in Molise) and close to zero in Tuscany. In Veneto, the potential efficiency gain is zero by construction.

[14] We also checked the impact on average efficiency of another policy, defined as the set of best values observed in 2016, i.e. the minimum values of EA (25.87 per cent in Tuscany) and of HO (4.02 per cent in Lombardy), the maximum value of PT (4.41 per cent in Basilicata) and imposing the integrated organisational model (d_int=*1*). In this case, the average level of efficiency is higher than the observed technical efficiency (95.5 per cent, +2.1 percentage points). However, this set of policy values has not been observed in practice and may not be feasible.

Table 4 - Potential efficiency gain and potential health expenditure savings (2016, current prices)

Regional health system	*Technical efficiency* $\widehat{TE}$ (%)	*Technical efficiency with best-practice policy* $\widehat{TE}^*$ (%)	*Potential efficiency gain* *PEG* (%)	*Current public healthcare expenditure* *E* *(€ per capita)*	*Minimum healthcare expenditure requirement* *ER* *(€ per capita)*	*Potential expenditure savings* *PES* *(%)*
Abruzzi	97.4	98.1	0.71	1,778.9	1,763.2	0.89
Apulia	94.7	96.8	2.06	1,770.0	1,724.0	2.60
Basilicata	81.2	84.1	2.95	1,793.6	1,717.3	4.25
Calabria	78.5	82.3	3.76	1,685.6	1,592.2	5.54
Campania	81.2	84.4	3.21	1,670.8	1,593.8	4.61
Emilia R.	94.8	95.2	0.43	1,897.5	1,887.0	0.55
Lazio	93.3	96.5	3.13	1,864.3	1,790.6	3.95
Liguria	95.5	96.9	1.49	1,999.8	1,962.1	1.88
Lombardy	97.7	98.2	0.52	1,868.4	1,856.2	0.66
Marche	97.4	97.9	0.57	1,786.6	1,773.9	0.71
Molise	78.8	83.3	4.53	2,014.5	1,882.1	6.57
Piedmont	97.4	97.8	0.37	1,825.0	1,816.4	0.47
Sicily	96.8	97.8	1.06	1,684.4	1,662.0	1.32
Tuscany	98.4	98.5	0.06	1,874.0	1,872.4	0.08
Umbria	97.7	98.2	0.45	1,844.9	1,834.4	0.56
Veneto	98.7	98.7	0.00	1,770.0	1,770.0	0.00
Weighted average	**93.4**	**94.9**	**1.48**	**1,807.4**	**1,776.0**	**1.77**

As mentioned in Section 1, previous studies have assumed that it is possible to eliminate inefficiency completely. We find, however, that even with the best-practice policy, no region achieved the production frontier $\widehat{TE}^* = 1$. Full efficiency could be achieved only with unfeasible healthcare policies. For instance, in our case, the region with the lowest efficiency score, Campania, could achieve almost 100 per cent efficiency only if the controlled variables were set at extreme and unrealistic values, i.e. no expenditure for services provided by private accredited providers (EA=0), 100 per cent share of expenditures for technical personnel (PT), and no resident population hospitalised outside the region (HO=0).

The previous results allow us to calculate the per capita expenditure requirement (ER) (equation (6)) and the corresponding values of the potential healthcare expenditure savings (PES) (equation (7)), assuming constant expected LEAs in each RHS. The results are shown in Table 4.

On average, the potential efficiency gain implies potential healthcare expenditure savings of 1.77 per cent, equal to 1.8 billion euro in 2016. In other words, if each of the 16 RHSs adopts the best-practice policy, public health expenditure can be reduced from 102.2 billion euro to 100.4 billion euro. The relation between technical inefficiency and potential expenditure savings is shown in Figure 1. Potential expenditure savings are higher for more inefficient RHSs, but PES (in %) are lower than inefficiency because with the best-practice policy chosen, complete efficiency is not reached. For RHSs with the highest levels of inefficiency, more than 18% in Basilicata, Campania, Calabria and Molise, savings range from only 4 to 6.5 per cent.

Figure 2 shows the geographical pattern of PES, which is characterised by a clear north-south divide, with the highest values in southern regions.

Figure 1 - Technical inefficiency and potential health expenditure savings (2016)

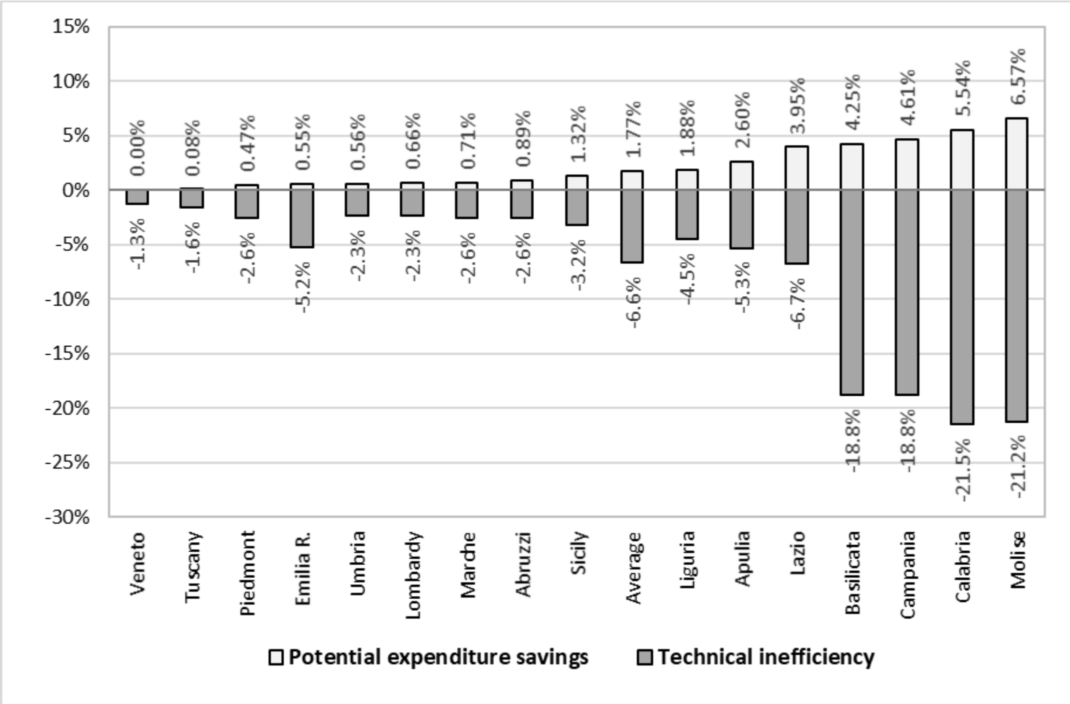
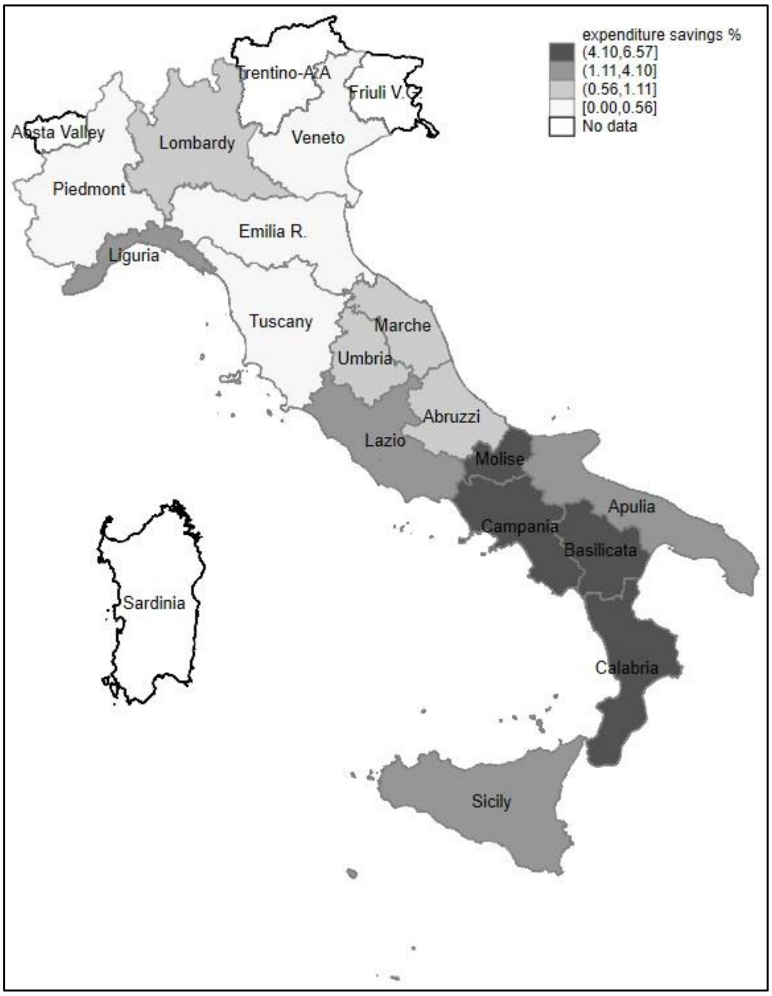


Figure 2 - Potential health expenditure savings (%) (2016)



6. Conclusions

Considering the LEA scores as outputs of the RHSs' production processes, we found that the technical efficiency of the 16 RHSs analysed averages 93.4 per cent, but shows high regional variability.

The estimate of the inefficiency model allowed us to identify the best policy among all organisational arrangements implemented by RHS policymakers, represented by four variables under the control of policymakers and managers: the share of expenditure on services provided by private accredited providers, the share of the hospitalised resident population hospitalised outside the region, the share of expenditure for technical personnel, and the type of organisational model. The best policy was defined as the set of values of the inefficiency determinants that maximises the Italian RHSs' aggregate efficiency.

We found the best policy among those implemented in 2016 to be the Veneto RHS's organisational arrangement. Its adoption by all regions would generate the maximum increase in average efficiency (+1.48 percentage points, from 93.4 to 94.9 per cent). We then calculated the amount of potential healthcare expenditure savings, which equalled 1.8 billion euro in 2016, about 1.77 per cent of current public healthcare expenditure.

Some policy implications should be highlighted. While the implementation of the best-practice policy leads to efficiency increases in all RHSs, the result is far from the best in absolute terms, as average efficiency remains at 94.9 per cent, and efficiency remains well below 90 per cent in some RHSs. How to reach the target of 100 per cent efficiency remains an unresolved issue both because it implies identifying a health policy specific to each RHS and because such a policy may not be feasible.

A potentially useful application of our method is the definition of standard healthcare expenditure levels that can be used in regional systems' financing models. Since Italian law would require uniform levels of essential care in all regions, the requirement function (6) can be used to determine the per capita public healthcare expenditure necessary to produce the desired uniform level of output when the inefficiency term is set at a uniform level in all regions.

The approach proposed in this paper has led to useful results regarding identifying best practices in the organisational arrangements of Italian RHSs and the effect of their implementation. However, the study has some limitations related to the definition of outputs and inputs of the production process, which most studies of this type share. Although we argued our choices on a theoretical basis, our results rely heavily on the assumption that the relevant input is health expenditure and that the LEA score is a measure of output that reflects central government preferences. Finally, the estimate of the expenditure savings relies on the assumption that the best-practice policy can be implemented in all regions. A promising line of research would consider alternative definitions of the best-practice policy, such as regionally differentiated policies.

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Appendix

Table A.1 - Hypothesis testing

	Null hypothesis H_0	*Alternative hypothesis* H_1	*Statistics and critical values*	*Conclusions*
Test against the complete model (LR test)	$\beta_k = 0;\ \delta_j = 0$ for all the *k* and *j* variables not in Model 1	$H_1: H_0$ false	χ^2 (3) = 2.25 $\chi^2_{0.95}$ (3) = 7.81 $\chi^2_{0.95}$ (3)[§] = 7.045	H_0 cannot be rejected
Test against the translog specification (LR test)	$\beta_{EE} = 0$ *(coefficient of E squared)*	$H_1: H_0$ false	χ^2 (1) = 1.63 $\chi^2_{0.95}$ (1) = 3.841 $\chi^2_{0.95}$ (1)[§] = 2.706	H_0 cannot be rejected
Test of specification (Link test)	Model 1 is correctly specified	Model 1 is not correctly specified	$z[coef(\hat{L}^2)]$ = -0.42 P>|z| = 0.673	H_0 cannot be rejected
Test against the hyp. of no inefficiency (LR test)	$\mu = \sigma_u^2 = 0$	$\mu \neq 0;\ \sigma_u^2 \neq 0$	χ^2 (4) = 78.45 $\chi^2_{0.95}$ (4) = 9.487 $\chi^2_{0.95}$ (4)[§] = 8.761	H_0 is rejected
Test against the half-normal model (LR test)	$\mu = 0$	$\mu \neq 0$	χ^2 (7) = 74,30 $\chi^2_{0.95}$ (7) = 14.06 $\chi^2_{0.95}$ (7)[§] = 13.401	H_0 is rejected
Test against the truncated-normal model (LR test)	μ constant	μ non-constant	χ^2 (5) = 65.12 $\chi^2_{0.95}$ (5) = 11.07 $\chi^2_{0.95}$ (5)[§] = 10.37c	H_0 is rejected

Legend: [§] *Kodde and Palm (1986), Table 1.*

Table A.2 - Aggregate efficiency when a RHS's policy is applied to all RHSs (2016)

	RHS policy values				**Aggregate efficiency**	
RHS	*Services provided by private accredited providers %*	*Expenditure for technical personnel %*	*Hospitalized outside the region %*	*Dummy for integrated model*	*Technical efficiency**	*Coefficient of variation of technical efficiency**
	EA	*PT*	*HO*	*d_int*	$\widehat{TE}$	
Abruzzi	33.06	3.29	15.97	1	93.69	0.0612
Apulia	39.64	2.65	8.70	0	93.12	0.0631
Basilicata	30.99	4.41	23.75	0	92.96	0.0636
Calabria	36.39	3.20	21.20	0	92.22	0.0655
Campania	40.21	2.11	8.89	0	92.76	0.0641
Emilia R.	28.88	4.18	6.25	0	94.62	0.0573
Lazio	43.02	1.86	9.29	0	92.41	0.0650
Liguria	31.41	3.95	15.71	0	93.53	0.0618
Lombardy	41.96	3.48	4.02	0	93.92	0.0603
Marche	29.64	4.33	13.46	0	94.02	0.0599
Molise	42.74	2.68	26.70	1	91.58	0.0669
Piedmont	32.07	4.16	7.55	0	94.37	0.0585
Sicily	38.33	2.82	7.10	0	93.45	0.0620
Tuscany	25.87	4.13	6.13	0	94.73	0.0567
Umbria	26.00	3.72	11.57	0	94.07	0.0598
Veneto	**32.97**	**4.08**	**6.36**	**1**	**94.90**	**0.0558**

*Legend: * weighted average*