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The impact of health policy and organisational models on Italian hospital productivity growth

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Abstract

The rapid increase in healthcare costs has drawn the attention of managers and policymakers towards regulating health expenditures: many countries have implemented deep reforms to improve efficiency and productivity in the provision of health services. In Italy, the central government has introduced austerity measures, called recovery plans, to force the administrative regions to reduce healthcare deficits. In this study, we first evaluate the impact of these recovery plans on hospitals' productivity by calculating the Malmquist productivity index using data envelopment analysis. Next, we regress the obtained productivity index and its components on a set of explanatory variables to capture the impact of the austerity measures, the moderating role of the regional organisational models, the variation in hospitals' size and management autonomy and the capital intensity. The data used to estimate productivity were for an extensive period – from 2006 to 2018. The results could contribute to assessing the increase in the productivity of hospitals and the influence of government policies on the same.

Keywords: data envelopment analysis; healthcare; hospitals; Malmquist; productivity; recovery plans

1. Introduction

In recent years, the health sector has grown faster than the economy. From 2000 to 2017, global health spending grew at an annual real rate of 3.9%, while economic growth was 3%. Specifically, (i) in middle-income countries, health spending increased by 6.3% per year, while the economy grew by 5.9% per year; (ii) in low-income countries, health spending increased by 7.8% per year, while the economy grew by 6.4%; and, (iii) in high-income countries, average annual growth was 3.5%, which was about twice the economic growth rate (World Health Organization, 2019). The rapid

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increase in health costs can also be attributed to the introduction of more expensive technologies and advances in hospital care. *Health technologies* refer to tools and techniques that are used to improve healthcare quality, detect diseases earlier, manage chronic conditions more effectively and ensure better patient care.

Furthermore, introducing new health technologies implies additional costs, including investments in equipment, human capital, digital skills and changes in organisational levels (Liao et al., 2016). In addition, newly developed treatments require that most patients be subjected to repeated visits or expensive hospitalisation, which often involve frequent diagnostic tests and special medical examinations, thus contributing to rising healthcare costs. Many countries with advanced healthcare systems have adopted policies to rationalise resource use and reduce healthcare expenditure by increasing the efficiency of service delivery organisations with respect to addressing these critical issues. These policies include the introduction of competition between healthcare providers, changes in reimbursement systems, new organisational models, budget caps and other reforms to achieve the same health outcomes using lesser financial resources. Different studies have evaluated the impact of these reforms and policies in terms of boosting hospital productivity and efficiency. Some argue that the introduction of financial constraints in order to control healthcare spending has had a positive effect on hospital productivity (Blank and Eggink, 2014; Sommersguter-Reichmann, 2000); others report that several efforts and additional factors must be considered to achieve an increase in productivity (Mancuso and Valdmanis, 2016; Karmann and Roesel, 2017).

Based on these findings, this paper uses the Malmquist productivity index to assess the impact of health policy reforms on Italian hospital systems from 2006 to 2018. Non-parametric data envelopment analysis (DEA) was used to calculate the Malmquist index, which can be decomposed into a 'technological change' and an 'efficiency change' component. It seems clear that productivity depends on the level of technology adopted and the efficiency with which it is utilised. Thus, we aim to investigate the relationship between government policies, technological endowments and increases in hospitals' productivity. Further, by analysing productivity dynamics and applying a regression model, we aim to determine whether other factors, such as regional organisational models, hospital dimensions and autonomy, capital intensity and other control variables, can lead to productivity gains in addition to austerity measures. The rest of the paper is structured as follows: Section 2 presents studies that have analysed significant European reforms, with a special focus on the Italian national healthcare system, containment measures and relevant literature. Next, Section 3 describes the methodology used, while Section 4 explains the data used for the analysis. Then, Section 5 presents and discusses the results, and, finally, Section 6 provides a brief conclusion.

2. Literature review

Several studies have analysed the effect of government reforms with regard to reducing healthcare spending and improving the efficiency of healthcare systems by optimising and redistributing resources. Karmann and Roesel (2017) examined the determinants of hospital productivity growth in the German federal states to find that improving the quality of hospital care and reducing patients' lengths of stay can lead to increases in hospital productivity. The authors also reported that other factors, such as hospital size, occupancy rate, specialisation and privatisation, positively impacted productivity but depended on the reimbursement system (fixed daily rates or diagnosis-related group funding).

Following the implementation of policy reforms, Atella et al. (2019) analysed and compared the levels of productivity of the English and Italian healthcare systems. The rise in productivity in the English healthcare systems was due to an increase in inpatient activity, while that in the Italian healthcare system was because of the outpatient activity. However, both healthcare systems went through alternating phases of increases and decreases in productivity from 2004 to 2011.

Studying the British healthcare systems, Valdmanis et al. (2017) analysed 43 Scottish hospitals to examine changes in their productivity from 2003 to 2007 after austerity measures were introduced. The measures' helped hospitals do more with less, contributing to productivity increases and improving patients' healthcare experiences.

Blank and Eggink (2014) present a historical analysis (1972–2010) of productivity changes in the hospital sector in the Netherlands. They analysed three different regulation approaches introduced by the government to curb healthcare expenditure and found that productivity improved when the Dutch healthcare system was under constant pressure due to various budget constraints.

In Portugal, several research studies have been conducted to assess the efficiency of public hospitals from different perspectives using DEA (Afonso et al., 2024). Duque-Uribe et al. (2019), Pederneiras et al. (2023) and Pereira et al., 2021a, 2021b) have contributed to this area of study. Duque-Uribe et al. (2019) conducted a systematic review that proposed an integrated framework of sustainable supply chain management practices to improve sustainable performance in hospital settings. They identified 12 categories of management practices and examined their impact on hospitals' economic, environmental and social performance. They also pointed out the lack of empirical studies on the effects of these practices and the potential trade-offs between the different dimensions involved.

Pederneiras et al. (2023) focused on evaluating the performance of Portuguese hospitals using a hybrid DEA model. Their analysis considered the relevant social, environmental and economic perspectives and revealed that most Portuguese public hospitals needed improvement with regard to economic sustainability, which emphasises the significance of adopting sustainable practices for the long-term viability of the healthcare system.

Pereira et al. (2021a) analysed the efficiency of Portuguese hospitals using composite indicators that were determined through a DEA conducted from the user and provider perspectives. The authors found that, out of 29 healthcare providers, seven were considered to be efficient from the users' perspective, while six were considered to be efficient from the providers' perspective.

Further, Pereira et al. (2021b) developed a new method for assessing the efficiency of Portuguese hospitals. They collaborated with decision-makers to validate and improve the model's accuracy, providing reliable information to assist healthcare managers and policymakers in their decision-making processes. The results identified nine out of 27 hospitals as being efficient from the optimal and real-world perspectives based on the judgements of the decision-makers.

Since the 1990s, Italy has also experimented with various reforms to reduce health expenditures and make hospital services more efficient and productive. Although it is possible to find several studies that have examined the efficiency of Italian hospitals (De Nicola et al., 2014; Colombi et al., 2017; Cavalieri et al., 2018; Giancotti et al., 2020; Piubello Orsini et al., 2021; Barra et al., 2022), only a few have explored their productivity. One such study was conducted by Mancuso and Valdmanis (2016), who analysed the Italian regional health systems from 2008 to 2012 and showed that, despite the reforms, hospitals still needed to achieve productivity gains by optimising resource use and exploiting existing technology. However, this work provides evidence only at a regional level and for a limited period of analysis without considering the specific characteristics of each hospital.

2.1. The Italian National Healthcare System

The Italian National Healthcare System (SSN) ensures citizens' health safety according to universality, equity and legality principles. The reforms implemented during the 1990s resulted in a substantial decentralisation of the SSN, transforming it into a 'system of regional health systems', in which the regions became responsible for promoting the health of the population, providing a package of standard health services (the so-called *Livelli essenziali di assistenza*, LEAs) and keeping their health expenditure within the established budgets (Mapelli et al., 2007). In other words, since the year 2000, the regions have decided their priorities, defined their strategy to meet the population's needs and allocated the budget for their systems (Nuti et al., 2016).

Italy has five regions with a 'special statute' compared to the others: *Valle D'Aosta*, *Trentino Alto Adige*, *Friuli Venezia Giulia*, *Sicilia* and *Sardegna*. These regions have specific powers with respect to education, health, cultural protection, territorial organisation and administrative and financial autonomy, which allows them to create laws and impose taxes as necessary. The rest of the regions are known as 'ordinary statute' regions.

Italian regions differ in terms of the type of health organisational system they employ and the relationship between the regional government and the healthcare providers. According to Ferré et al. (2014) and De Nicola et al. (2014), it is possible to categorise them into three systems: *Aziende Sanitarie Locali* (ASL)-centred model, region-centred model and purchaser–provider split model. In the ASL-centred model, the local health authorities (ASLs) have complete autonomy and can contract public and private healthcare providers. In contrast, in the region-centred model, the regional government limits the autonomy of the ASLs: the former acts as a purchaser by directly financing providers such as ASLs, independent organisations (*Aziende Ospedaliere* [hospital enterprise], *Aziende Ospedaliere Universitarie e Policlinici Universitari* [teaching hospitals] and *Istituti di ricovero e cura a carattere scientifico* [public research institutes]) and accredited private hospitals based on their activities. In the purchaser–provider split model, the ASLs act only as purchasers, leaving the providers' activities to independent organisations and accredited private hospitals. This system maintains a well-defined separation between health service providers and purchasers. Based on these considerations, De Nicola et al. (2014) analysed hospital efficiency for these three organisational models. Their analysis, carried out using data for the district level and a two-stage DEA technique for the period of 2004–2005, revealed that the degree of administrative decentralisation from regional governments to ASLs must be generally balanced; in contrast, a decentralised system can lead to inefficiencies. Table 1 summarises the described organisational system for the 21 Italian regions.

The level of decision-making autonomy granted to the hospital management depends on the type of hospital. These are categorised by legislation as follows: *ospedali a gestione diretta e presidi ospedalieri* (district general hospitals), which are directly managed by ASLs; hospital enterprises, teaching hospitals and public research institutes, which are independent organisations; and

Table 1
Regional characteristics

Region	Organisational model
Abruzzo	Regional centred
Basilicata	ASL centred
Bolzano	ASL centred
Calabria	ASL centred
Campania	Regional centred
Emilia-Romagna	ASL centred
Friulia Venezia Giulia	Regional centred
Lazio	ASL centred
Liguria	ASL centred
Lombardia	Purchaser–provider
Marche	ASL centred
Molise	Regional centred
Piemonte	ASL centred
Puglia	ASL centred
Sardegna	ASL centred
Sicilia	Regional centred
Toscana	ASL centred
Trento	ASL centred
Umbria	ASL centred
Valle d'Aosta	ASL centred
Veneto	ASL centred

non-profit hospitals and other facilities (such as single-specialty hospitals, including orthopaedic rehabilitation centres, residential facilities with long-term care beds and mental healthcare institutions).

2.2. *The recovery plans*

Public spending on healthcare in Italy has always presented an irregular trend. Periods of sustained growth, during which spending was out of control, have been followed by periods of budget constraints enforced by central government intervention (Fig. 1).

Decentralisation has significantly impacted specific regions' public debt and deficits, leading to substantial differences between them. In this context, the central government transfers funds to regions responsible for spending in order for them to provide healthcare services. In such systems, the problem of controlling subnational governments' deficits is quite common all over the world (Bordignon et al., 2020). There is an implicit incentive for subnational governments to increase their spending, leading to financial irresponsibility, if appropriate control mechanisms are not introduced. Several mechanisms have been proposed in the literature to address these issues related to subnational governments, such as fiscal instruments (i.e., local taxes) and fiscal rules.

In Italy, during the 1990s, the central government often resolved regional healthcare deficits without imposing any restrictions or penalties for the incorrect allocation of resources or the lack of economic results. Therefore, significant healthcare deficits existed for several years in some regions without a specific sanction mechanism to encourage expenditure constraints. As reported by

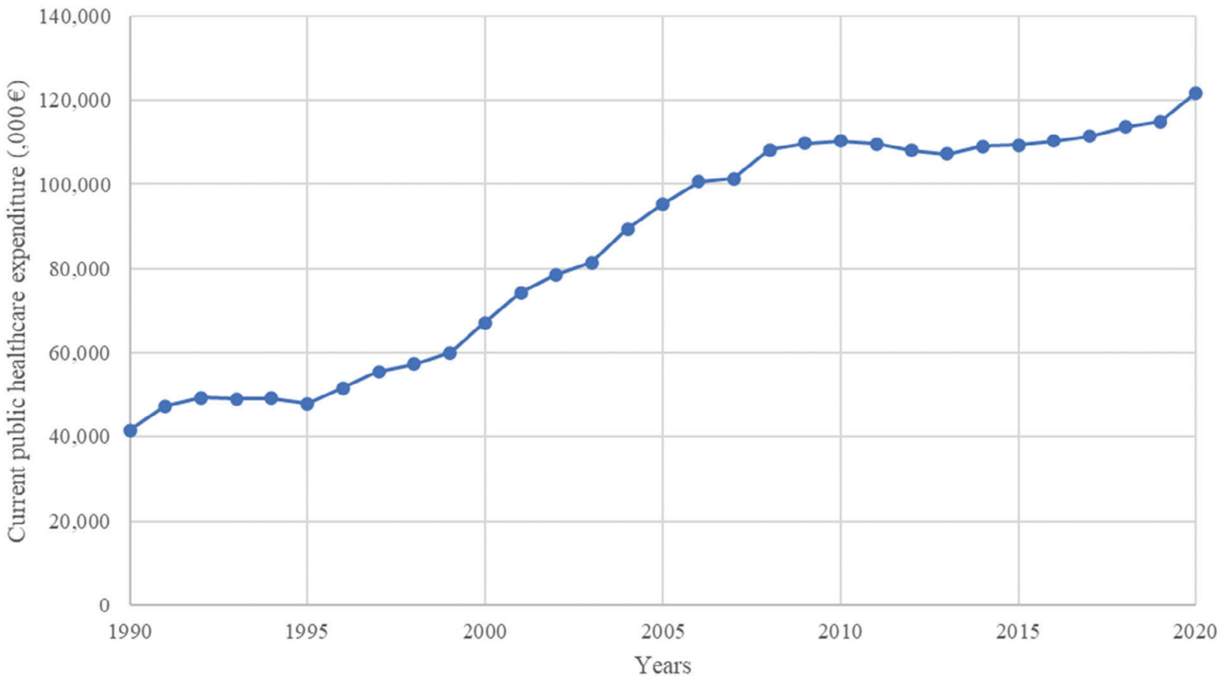


Fig. 1. Evolution of current public health expenditure since 1990s.

Aimone et al. (2018) and Bordignon et al. (2020), to address the financial irresponsibility of regions and facilitate deficit correction, a new control mechanism – an alternative to fiscal instruments and fiscal rules – was introduced in 2007 by the central government: the recovery plans (RPs). This new control mechanism established 'administrative subordination' and represented a binding programme to reduce regional deficits. In particular, regions with deficits exceeding 7% of their total funds (reduced to 5% in 2010) would be required to propose an RP approved by the Ministry of Health and the Ministry of Economy and Finance. The RPs were a tool aimed at restoring the financial conditions of regions by containing healthcare costs, improving the appropriateness of the care provided, limiting staff turnover, introducing caps on new hires and rationalising the use of hospital beds. Regarding the limits on structural allocations, such as the number of hospital beds, several specific parameters were imposed; for instance, regions needed to have 3.7 beds per thousand inhabitants, of which 3.0 needed to be for acute care and 0.7 for rehabilitation and long-term care (Aimone et al., 2018).

The RPs were to remain valid for three years, but if the objectives had not been achieved at the end of the period, the plans would be automatically renewed for an additional three years. In the event of non-compliance, the central government would appoint a commissioner, who would be responsible for the effective implementation of the plan. It is essential to point out that the region's president was often appointed as the commissioner, but this was a controversial decision. Some researchers believe that appointing a professional with expertise and experience in managing health services, and not a former politician, was necessary (Bordignon et al., 2020). This more restrictive approach also prevented investment in non-essential expenditures, such as research and

Table 2
Evolution of RPs in Italian regions

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Abruzzo	X	RP	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RP	RP
Basilicata	X	X	X	X	X	X	X	X	X	X	X	X	X
Bolzano	X	X	X	X	X	X	X	X	X	X	X	X	X
Calabria	X	X	X	RP	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC
Campania	X	RP	RP	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC
Emilia Romagna	X	X	X	X	X	X	X	X	X	X	X	X	X
Friuli Venezia Giulia	X	X	X	X	X	X	X	X	X	X	X	X	X
Lazio	X	RP	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC
Liguria	X	RP	RP	RP	X	X	X	X	X	X	X	X	X
Lombardia	X	X	X	X	X	X	X	X	X	X	X	X	X
Marche	X	X	X	X	X	X	X	X	X	X	X	X	X
Molise	X	RP	RP	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC	RPC
Piemonte	X	X	X	X	RP	RP	RP	RP	RP	RP	RP	X	X
Puglia	X	X	X	X	RP	RP	RP	RP	RP	RP	RP	RP	RP
Sardegna	X	RP	RP	RP	X	X	X	X	X	X	X	X	X
Sicilia	X	RP	RP	RP	RP	RP	RP	RP	RP	RP	RP	RP	RP
Toscana	X	X	X	X	X	X	X	X	X	X	X	X	X
Trentino	X	X	X	X	X	X	X	X	X	X	X	X	X
Umbria	X	X	X	X	X	X	X	X	X	X	X	X	X
Valle D'Aosta	X	X	X	X	X	X	X	X	X	X	X	X	X
Veneto	X	X	X	X	X	X	X	X	X	X	X	X	X

Note: RP = standard recovery plan; RPC = presence of the commissioner; X = no recovery plan in force.

development. The RPs are still active in about seven of the 21 regions, and Table 2 shows the evolution of the RPs in the different Italian regions; many have had to resort to intervention by a commissioner.

The introduction of RPs at the regional level attracted the interest of many researchers, who have studied their consequences and effects on the Italian healthcare system. Bordignon et al. (2020) highlighted the significant results of these austerity measures in relation to reducing the regional deficit with no significant impact on health outcomes and the use of healthcare services. They used a difference-in-differences approach on a panel of Italian regions for the period of 2000–2014. Conversely, Depalo (2019) and Arcà et al. (2020) emphasised the negative effects of RPs on mortality rates. Specifically, Depalo (2019) found that reductions in healthcare expenditures resulted in proportionate decreases in hospital admissions and, consequentially, in the volume of patients treated. He also observed a negative effect on mortality rates without gains in efficiency. Arca et al. (2020) estimated that the RPs policy resulted in a 3% rise in avoidable deaths based on regional data for the period of 2004–2014. In addition, previous literature on RPs underlines that this policy successfully reduced health deficits but with unclear effects on healthcare outcomes.

The present paper analyses the relationship between the RPs, the organisational model and the productivity of Italian hospitals. In other words, we investigate whether the austerity measures and the peculiarities of the regional organisational models influenced hospitals' productivity and its components (efficiency change and technological change). This paper contributes to the existing literature in several respects.

First, we present an updated analysis of Italian hospitals' productivity from 2006 to 2018. Our analysis considers four periods: the first begins in 2006, the year before the implementation of the RPs, and ends in 2009, the last year of the first three-year period of the RPs. The other periods follow the three-year trend of RPs: the second one begins in 2009 and ends in 2012, the third begins in 2012 and ends in 2015, and the fourth begins in 2015 and ends in 2018. This time decomposition allowed us to analyse the reaction of Italian hospitals to the introduction and renewal of RPs. The productivity results can provide valuable insights into the efficient use of resources and the level of technological advancement in hospitals. Managers and policymakers need to have a comprehensive understanding of current healthcare technology, which has the potential to significantly improve patient care and diagnostic processes.

Second, the impact of RPs on hospital productivity is evaluated together with regional organisational models to analyse their combined effects. We assume that the impact of RPs on productivity can be moderated (enhanced or reduced) based on the organisational model adopted by the region. It is important to understand that a particular policy may only work effectively for some regions and should be adjusted based on the organisational model adopted.

Finally, these insights are crucial for those creating future healthcare policies and practices and making organisational, planning and political decisions.

3. Methodology

We employed a two-stage procedure to analyse the effects of regulatory changes on the productivity of Italian hospitals. In the first stage, we calculate the productivity of Italian hospitals between the year before the possible introduction of RPs and the last year of the three-year RP period. In the second stage, we regress the productivity index and its components on explanatory variables to capture the introduction of the austerity measures, the regional organisational model, hospital growth, capital intensity, type of hospital and control variables.

3.1. Malmquist index

In this study, we calculated the variation in productivity using the Malmquist productivity index. This index is defined using distance functions. Let $x = (x_1, \ldots, x_N) \in R_+^N$ denote a vector of inputs and $y = (y_1, \ldots, y_M) \in R_+^M$ be an output vector. An input distance function considers the minimum proportional contraction of the input vector given an output vector, while an output distance function considers the maximum proportional expansion of the output vector given an input vector. Since we wanted to measure the extent to which the output quantities can be proportionally expanded without altering the number of input quantities used, only an output distance function has been considered in this paper. This is consistent with previous studies (De Nicola et al., 2014; Karmann and Roesel, 2017) and has been done because labour laws fix certain hospital inputs (i.e., the number of personnel) and the objective becomes the maximisation of the output (attracting and treating more patients who can choose where to be treated) using the given amount of input resources. Next, we assume that the hospital management maximises the number of services provided within the given budget. It is important to highlight that the Malmquist productivity index is defined under the 'constant returns to scale' assumption. In this case, the two measures (input- and output-oriented) are equivalent. However, as we wanted to assess whether the reduction in health expenditure due to RPs still hinders productivity, we calculated the output-oriented Malmquist index.

The output-oriented Malmquist productivity index considering the t-period as reference technology is defined as follows:

$$M_o^t = \frac{D_o^s\,(x^t,\ y^t)}{D_o^s\,(x^s, y^s)}. \tag{1}$$

Here, s and t denote two time periods, $D_o^s(x^s, y^s)$ represents the value of the output distance function related to the technology in the period s and the input–output vector in the same period and $D_o^s(x^t, y^t)$ represents the value of the distance function for the input–output vector of period t and the technology at time s.

Inspired by Caves et al. (1982), and following the work of Färe et al. (1994), we defined the output-oriented Malmquist index as the geometric mean of (1) at period s and t:

$$\begin{aligned} M_o\ \left(x^s, y^s, x^t, y^t\right) &= \left(\frac{D_o^s\,(x^t, y^t)}{D_o^s\,(x^s, y^s)}\frac{D_o^t\,(x^t, y^t)}{D_o^t\,(x^s, y^s)}\right)^{\frac{1}{2}} = EFFCH\ \times\ [TECHCH] \\ &= \frac{D_o^t\,(x^t, y^t)}{D_o^s\,(x^s, y^s)} \times \left[\frac{D_o^s\,(x^t, y^t)}{D_o^t\,(x^t, y^t)}\frac{D_o^s\,(x^s, y^s)}{D_o^t\,(x^s, y^s)}\right]^{\frac{1}{2}}. \end{aligned} \tag{2}$$

If the value of M_o is greater than one, it will indicate an increase in productivity from period s to period t, while a value of less than one will indicate a decline in productivity.

The DEA method was used to measure the distance functions that make up the Malmquist index. According to Färe et al. (1994, 1998), DEA allows for the exhaustive division of the Malmquist productivity index into useful component measures: technological change (TECHCH) and efficiency change (EFFCH). The first source of productivity, which is inside square brackets in Equation (2), represents a shift in production technology, while the second represents a movement towards production technology. TECHCH measures a hospital's ability to be more (or less) productive with a given vector of inputs. EFFCH measures a hospital's ability to use its inputs more efficiently and exploit the available technology. As for the productivity index, the technological and efficiency change can be greater or less than one, indicating growth (>1) or decline (<1), respectively.

To calculate the productivity index in Equation (2), four linear programming problems needed to be solved. The linear program required to obtain $D_o^s(x^s, y^s)$ was as follows:

$$\begin{aligned} &\left[D_o^s\,(x^s, y^s)\right]^{-1} = \theta \\ &\text{s.t. } x_s\ \geq X_s\lambda \\ &\theta y_s \leq Y_s\lambda \\ &\lambda \geq 0. \end{aligned} \tag{3}$$

Here, Y_s is the matrix of the observed output at time s, X_s is the matrix of the observed input at time s, and they represent the technology of production at time s; θ is the proportional increase in the output, and λ represents a vector of weights that allows a convex combination of inputs and outputs. In a similar manner, $D^t_o(x^t, y^t)$ was calculated by substituting t for s in linear program (3).

However, the calculation of the distance function refers to two different moments in time $D^s_o(x^t, y^t)$ is different and was calculated as follows:

$$\left[D^s_o\left(x^t, y^t\right)\right]^{-1} = \theta$$

$$s.t.\ x_t \ \geq X_s\lambda \tag{4}$$

$$\theta y_t \leq Y_s\lambda$$

$$\lambda \geq 0.$$

Here, Y_s is the matrix of the observed output at time s, X_s is the matrix of the observed input at time s and they represent the technology of production at time s; (x^t, y^t) are the outputs and inputs of the hospital under investigation at time t. Finally, $D^t_o(x^s, y^s)$ was calculated in the same manner by substituting s with t and t with s.

3.2. Regression analysis

In the second stage, we estimated a regression model to assess the effects of a set of exogenous variables on the healthcare productivity and its components obtained during the first stage. The linear multiple regression models can be formulated as follows:

$$M_{i,t} = Z_{i,t}\ \beta + \varepsilon_{i,t}, \tag{5}$$

$$EFFCH_{i,t} = Z_{i,t}\ \beta + \varepsilon_{i,t}, \tag{6}$$

$$TECHCH_{i,t} = Z_{i,t}\ \beta + \varepsilon_{i,t}. \tag{7}$$

Here, $M_{i,t}$ represents the change in productivity, $EFFCH_{i,t}$ is the efficiency change and $TECHCH_{i,t}$ is the technological change of hospital i in period t; $Z_{i,t}$ is a set of explanatory variables for each hospital i at time t, and $\varepsilon_{i,t}$ is the error term. The Malmquist productivity index is a rate of distance functions, and we estimated the regression model by applying ordinary least squares (OLS) with a heteroskedasticity robust standard error. Time fixed effects were included, controlling for effects that vary over time, that is, eliminating time-varying omitted variable bias. Regional fixed effects were not included because the variable population of the region is also region specific.

Table 3
Number of hospitals by type and period of analysis

Type of hospital	2006–2009	2009–2012	2012–2015	2015–2018
Independent hospitals	96	79	87	75
Non-independent hospitals	306	253	272	181
Total number of hospitals	402	332	359	256

Table 4
Description and role of variables

Variables	Description	Role of variables
Physicians	Total number of physicians	Input
Nurses	Total number of nurses	Input
Other employees	Total number of employees in the hospital other than physicians and nurses	Input
Beds	Total number of hospital beds, obtained as the sum of outpatient and inpatient beds	Input
Inpatients × CMI	Total number of inpatients multiplied by the hospital case-mix index (CMI)	Output
Outpatients	Total number of outpatient visits	Output
Surgical procedures × CMI	Total number of hospital surgical procedures multiplied by the hospital case-mix index (CMI)	Output

4. Data and variables

The Italian Ministry of Health provided the data used for the analysis, which were for 2006–2018. As mentioned in Section 2, our sample includes independent hospitals (hospital enterprises, teaching hospitals and public research institutes) and dependent hospitals (district general hospitals).

In our sample, we include hospitals that have more than 29 physicians, more than 79 nurses, more than 49 employees, more than 49 beds, more than 999 inpatients and more than 999 surgical procedures. Our sample covers 67.7% and 54.6% of Italian hospitals in 2006 and 2018, respectively. As stated in the discussion of the Introduction and renewal of RPs, our analysis considers four periods: 2006–2009, 2009–2012, 2012–2015 and 2015–2018. The number of hospitals included in the analysis by type and year is reported in Table 3. This indicates that the number of Italian hospitals decreased significantly between 2006 and 2018; in particular, the number of independent hospitals reduced by 21.9%, while that for dependent hospitals reduced by 40.8%. According to Giancotti et al. (2020), this decline occurred because many hospitals were merged and aggregated between 2010 and 2013 to reduce public spending.

Following the empirical literature on healthcare performance measurement using DEA (De Nicola et al., 2012; Kounetas and Papathanassopoulos, 2013; Pilyavsky et al., 2006; Roth et al., 2019), we used four inputs (number of beds, physicians, nurses and other employees) and three outputs (number of inpatients, outpatients and surgical procedures) to estimate hospital productivity (see Table 4). Patients who spent at least one night in the hospital were considered *inpatients*, while those who entered and left the hospital on the same day were considered *outpatients*. In our study, the number of beds was equal to the sum of outpatient and inpatient beds. The latter indicates the number of beds available for the treatment of inpatients, while the former indicates the number of beds available for outpatients. Measuring capital in the healthcare sector is difficult, so we use the number of beds available as a proxy, as done in previous studies (Grosskopf et al., 2004; Aletras et al., 2007; De Nicola et al., 2014; Roth et al., 2019). Previous research states that hospitals with a large capacity (more beds) have lower operating costs per patient day than smaller hospitals (Ding, 2014; Roth et al., 2019). Furthermore, as discussed in Section 2, rationalising the use of hospital beds is one of the RP guidelines, as a reduction in the number of beds is expected to decrease healthcare spending.

The inputs and outputs were expressed in terms of physical quantities. The hospitals' labour was measured by the number of physicians, nurses and other employees. Considering the selected outputs, patients treated in hospitals differ in terms of the complexity of their conditions and require different levels of attention depending on the simultaneous presence of several diseases. For this reason, we decided to multiply inpatients and surgical procedures by the hospital case-mix index (CMI) to gauge them by the intensity of treatment received (Ferreira and Marques, 2016).

Cuts in healthcare expenditure mainly affect the number of beds and healthcare staff resources, as these are the most expensive components of this public expenditure. Table 5 provides summary statistics for inputs and outputs. We report both the mean and the median, as the latter is a more robust estimator of the central value, which does not change even when an outlier remains close to the original statistical distribution (de Nijs and Klausen, 2013).

As for the human resources included in the analysis, the most significant decrease occurred between 2012 and 2015: the medians for physicians, nurses and other employees decreased by 7.8%, 7.7% and 4.8%, respectively. However, between 2015 and 2018, there was a slight increase in the number of physicians (2.6%) because the hospitals located in regions under the RPs could hire more physicians to promote the improvement of the LEAs. Generally, the cost-containment strategy led hospitals to change the characteristics of their workforce in terms of size, average age and roles. In fact, while reducing the number of healthcare staff was shown to help contain spending, the rising average age of the workforce tended to reduce savings, as older staff are characterised by higher salaries.

Regarding the number of beds, the most significant decrease occurred between 2015 and 2018 (−11.0%), following a −6.6% decrease in the previous three-year period. These decreases mainly affected the *medicine* and *general surgery* departments, certain medical specialisations (*neurology*, *otolaryngology*, *ophthalmology* and *dermatology*) and the number of inpatient and outpatient beds (Aimone et al., 2018). Between 2015 and 2018, there was the most significant reduction in the number of inpatients and outpatients −14.0% and −7.3%, respectively. Therefore, it can be concluded that reductions in bed allocation reduce hospital capacity in terms of the number of patients treated.

In the second stage, we included an ordinary variable that took into account the three-year periods in which a region was subjected to an RP. This variable was intended to measure the impact of RPs on hospital performance. Specifically, it helped us determine whether the effect of RPs is influenced by how long hospitals have adhered to an RP's guidelines. The longer a region is subjected to an RP, the less effective the austerity measures become. Furthermore, a dummy variable equal to 1 was introduced if a commissioner was appointed in the region with an active RP.

We included two variables of hospital policy measures: change in hospital size and capital intensity. The variable 'change in hospital size' was measured by considering the average between the relative change in the number of beds and the relative change in total staff. The ratio between

Table 5
Summary statistics of input and output variables

Variable	Year	Min.	Median	Mean	Max.
Physicians	2009	32	157	229.43	1174
	2012	31	185.5	242.3	1071
	2015	34	171	243.2	1509
	2018	34	175.5	251.3	1497
Nurses	2009	83	350.5	534.7	2409
	2012	82	439	586	2378
	2015	90	405	579.1	3730
	2018	91	388.5	564.3	3784
Other employees	2009	52	240.5	440.4	2824
	2012	51	304.5	469.1	2754
	2015	53	290	462.8	4428
	2018	52	283.5	428.5	4290
Beds	2009	53	285.5	410.7	1918
	2012	65	335	424.4	1728
	2015	54	313	402.8	2150
	2018	66	278.5	376.4	2124
Outpatients	2009	21	1134	1854.7	37,227
	2012	14	1191	1808.5	10,563
	2015	13	1118	1665	10,417
	2018	24	1036	1694.2	10,165
Inpatients × CMI	2009	1160	10,274	14,134	67,721
	2012	1578	11,103	14,330	61,821
	2015	1387	10,668	13,675	66,954
	2018	1460	9,178	13,136	65,009
Surgical procedures × CMI	2009	1055	10,029	18,228	147,388
	2012	1066	13,352	18,940	127,459
	2015	1146	12,180	18,907	149,792
	2018	1562	11,890	21,335	172,120

the number of beds and the number of physicians denoted capital intensity: this variable was introduced because the proportion of capital and labour is usually determined by hospital managers (Karmann and Roesel, 2017).

The hospital type was a dummy variable and reflected the autonomy of the hospital manager in relation to the local health authority. The impact of the regional organisational model was captured with a set of dummy variables according to the model adopted by the region. An interaction variable between the RP periods and the region-centred model was included in the model to test the moderating effect (Dawson, 2014). In particular, we tested whether the impact that RPs had on hospitals' performance depended on the regional organisational model. The interaction variable between the purchaser–provider split model and the RP periods was omitted because no regions with this organisational model were subjected to RPs.

Further, we controlled for specific regional factors, such as the population and special statutes. Control variables, such as income and health expenditure per capita, were excluded because they were highly correlated with the dummy identifiers of the regions with RPs. A region's resident population was calculated as the average between the analysed periods. A binary variable was

Table 6
Regressors selected in the second stage

Variable	Description
RP periods	Number of three-year periods in which the region was subjected to an RP
Commissioner	Dummy variable; 1 if a commissioner was appointed in the region with an RP
Change in hospital size	Change in hospital size based on the main inputs (beds and physicians)
Capital intensity	Ratio between the number of beds and the number of physicians
Population	Resident population of the region
Special statute	Dummy variable; 1 if the region had a special statute
Hospital type	Dummy variable; 1 for dependent hospitals
Time fixed effects	Dummy variable for the periods of 2009–2012, 2012–2015 and 2015–2018
Purchaser–provider split model	Dummy variable; 1 if the region used the purchaser–provider split organisational model
Region-centred model	Dummy variable; 1 if the region used the region-centred organisational model
RP periods × region-centred model	Interaction between the RP periods and the region-centred model

included if the region had a special statute because such regions are governed by specific autonomy conditions. Dummy variables for the years were included as time fixed effects. Table 6 shows the selected explanatory variables (regressors) operationalising the arguments presented in the first two sections.

5. Results

5.1. Hospital productivity results

We tested whether the constant-results-to-scale assumption held for our sample using the test proposed by Simar and Wilson (2020). Performing the test for each year, we failed to reject the null of the constant-returns-to-scale technology, with *p*-values in the range of 0.192–0.605 (the statistic tau was in the range 0.488–0.667).

In Fig. 2, we report the average performance of hospitals: we distinguished between hospitals located in regions that were subjected to RPs and those located in regions that were not. Our findings are seemingly counterintuitive: the reduction in the number of beds due to the austerity measures was expected to lead to a more efficient use of resources by decreasing the number of inappropriate admissions, converting inpatients to outpatients where possible due to lowered complexity and shifting some services to cheaper non-hospital care facilities (Aimone et al., 2018). However, we observed a decline in average productivity in the early periods, with a substantial lack of change by the third period. This implies that improving productivity requires more than simply reducing physical and human resources: hospitals need to learn how to organise and allocate the available resources optimally and use existing technologies. Regardless, this learning process requires complementary investments in knowledge and training; decision-makers need to be able to distribute resources equitably, and all healthcare staff need to be able to use the innovations and technologies in the hospital where they work. Again, in the early periods, on average, the technological change component was also less than 1, but there was an improvement during the later periods. This result can be attributed to the constant pressure on the healthcare system imposed by the various budget constraints, which reduce the introduction of expensive new technologies in the long run

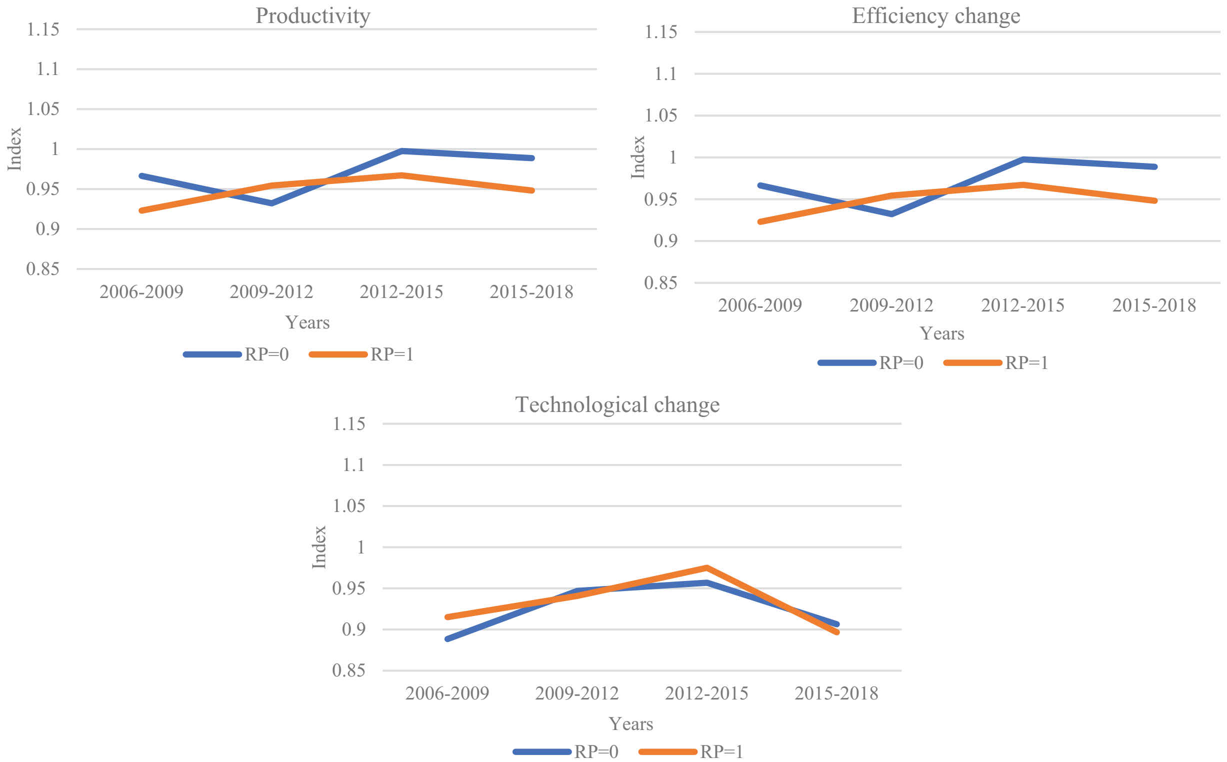


Fig. 2. Performance results for Italian hospitals

and limit the vision of challenging information and communication technology solutions based on cloud computing and mobile health.

The hospitals located in non-RP regions had, on average, higher productivity than those located in RP regions. In fact, between 2010 and 2014, the former performed better, mainly due to the efficiency change. This means that the hospitals of these regions learned to use their resources more efficiently and take advantage of all available pioneering tools. As for the technological change in the hospitals located in the non-RP regions, the result is unexpected: hospitals not constrained by healthcare spending should not prevent investment in research and development and technology, as innovative techniques for patient care can make a considerable difference in the healthcare sector. Although, organisations need time to adopt newly developed technologies and become familiar with innovative processes (Liao et al., 2016).

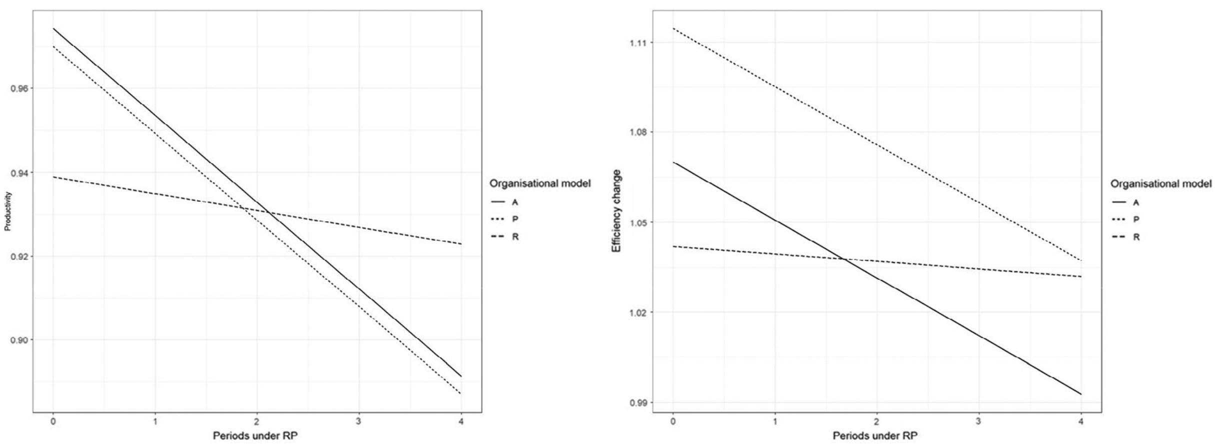
5.2. *Regression results*

Table 7 presents the results of the regressions. The dependent variables are the productivity change and its components: efficiency change and technological change. In addition, we interacted with the organisational-model variable with the RP-periods variable to determine whether its effects depend on the duration of the more 'restrictive' austerity measures.

Table 7
Second stage results – Malmquist productivity (M), efficiency change (EFFCH) and technological change (TECHCH)

	M		TECHCH		EFFCH	
Predictors	Estimates	*p*	Estimates	*p*	Estimates	*p*
(Intercept)	1.016	**<0.001**	0.905	**<0.001**	1.125	**<0.001**
Population	−5.39e−9	**0.033**	8.86e−10	0.492	−7.42e−9	**0.007**
Change in hospital size	−0.287	**<0.001**	−0.03	**0.048**	−0.276	**<0.001**
Capital intensity	0.063	**<0.001**	0.035	**<0.001**	0.032	**0.001**
RP periods	−0.021	**0.001**	−0.001	0.66	−0.019	**0.004**
Commissioner	0.029	**0.029**	0.009	0.197	0.02	0.172
Hospital type	−0.022	**0.013**	0.004	0.322	−0.027	**0.005**
Special statute	−0.015	0.22	0	0.982	−0.017	0.204
Purchaser–provider split model	−0.004	0.838	−0.038	**<0.001**	0.044	**0.049**
Region centred model	−0.035	**0.023**	−0.01	0.195	−0.028	0.097
RP periods × region centred model	0.017	**0.031**	0.001	0.818	0.017	**0.046**
Time fixed effects	Yes		Yes		Yes	
Observations	1349		1349		1349	
R^2/R^2 adjusted	0.115/0.106		0.194/0.186		0.102/0.093	

Note: Values in bold indicate statistical significance at the 5% level.



(a) (b)

Fig. 3. Moderating effect of the regional organisational model on the performance relationship of the RP periods

Following the work of Dawson (2014), we plotted the moderation effects in Fig. 3 to be able to interpret it visually. We obtained an interesting result regarding the moderating effect of the organisational model (the variables ASL-centred model, region-centred model and purchaser–provider split model) and the RP periods. For the hospitals located in the regions that adopted the ASL-centred model, the impact of the RP periods on the productivity and efficiency change was negative. In contrast, when regions adopted the region-centred model and had active RPs for a longer duration, the decline in productivity was found to be less severe. Hence, there was a significant conditional effect. This marginal effect could entail that hospitals performed better when the RPs had been implemented and when the region was responsible for economic and financial management. In other words, if the regional government is aware that it has limits with respect to spending and limiting staff turnover due to RPs and, at the same time, can decide how to allocate, rationalise and assign its human and financial resources by adopting the region-centred model, it can better supervise all its activities and operate more efficiently. Therefore, a centralised system is preferable at the regional level. This result is consistent with *contingency theory*, which predicts that the relationship between an organisation's characteristics and performance depends on specific contingencies (Donaldson, 2001; Franco-Santos et al., 2012). In fact, as the *contingency theory* argues, no standard management model can be adapted to all regions; each of them should organise its economic and financial objectives according to its specific 'contingencies' (internal and external circumstances).

This result allows us to draw a further conclusion: the combined use of RPs and the region-centred model may also help reduce the opportunistic behaviour of some regional councils that led the central government to take action in 2007.

The presence of a commissioner was found to have a positive effect on productivity and its components. In the regions that were subjected to a commissioner's intervention and that did not achieve the objectives of the implemented RPs, the chief executive officers, chief medical officers and chief administrative officers of all the hospitals and local health authorities in the regions, as well as of the Ministry of Health in the regional executive, were dismissed. These serious consequences created significant pressure on the regional council, which realised that it risks a lot if it did not achieve the RP's objectives.

For every type of regional organisational model, the higher the number of periods for which the region was subjected to RPs, the more negatively the hospitals' performances were impacted. Although a decline in productivity was observed, the effect of RPs on efficiency change was positive (efficiency change >1; Fig. 3, Panel b). Further, the hospital managers in regions with a higher number of RP periods were improving the organisation of healthcare services, but this improvement was not evident in the productivity outcomes. The *Lewin model* can explain this finding; it is used when an organisation is restructured to improve its efficiency and competitiveness (Lewin, 1947; Armenakis and Bedeian, 1999). The RPs represented a significant change for hospitals, which had to reorganise their resources while ensuring the provision of adequate care (LEA). According to this model, change must be planned and structured and must occur in a sequence of three moments: (i) when the need for change is recognised and shared with those involved, (ii) when the change is implemented in the organisation processes and (iii) when the change is consolidated and accepted by the organisation.

In the case of the RPs, the need for change was identified in 2007, when the regions' deficits were high; the second phase is almost complete, as a positive impact of the austerity measures on efficiency is visible; the third phase is still pending. Indeed, the impact of the RPs on productivity was negative, indicating that the changes have yet to be accepted by all hospital organisations and have not become an integral part of their culture yet. We suggest that hospital managers organise discussion groups to help healthcare staff share and understand the reasons for the austerity measures. Reducing healthcare spending was a necessary measure to ensure the system's sustainability at the time.

Dependent hospitals performed relatively worse with regard to the productivity and efficiency change. This could be because these hospitals receive a fixed amount of funding from the local health authorities to provide a specific number of chargeable services, which cannot be increased, and the managers have limited decision-making autonomy. As a result, more healthcare services than those that have been budgeted for are often supplied without funding. In contrast, independent hospitals receive funding based on the services they provide using the diagnosis-related groups system. Thus, even when dependent hospitals are incentivised to increase efficiency while maintaining high levels of quality, they often fail because of the high costs involved and the spending cap, which are exacerbated by the introduction of RPs.

The regression analysis demonstrated that the variable capital intensity positively influenced productivity as well as the technological and efficiency change. This means that a decrease (increase) in the number of physicians while keeping the number of beds constant, causes an improvement (decline) in productivity and its components. This is also consistent with the result related to the change in hospital size, which has a significant negative coefficient. The findings associated with both capital intensity and change in hospital size align with the RPs' purpose because hospital managers are required to expand health services, such as the number of discharges and surgical procedures, with the same amount of inputs (physical and human resources). Since, on average, there has been no increase in the number of physicians required by the RP measures, the regions have complied by limiting turnover, positively influencing hospital efficiency.

Moreover, the decreasing number of physicians represents a potential loss of the knowledge, skills (in terms of the ability to use advanced techniques) and experiences that multidisciplinary teams can offer. Hence, the positive effect of capital intensity on technological change can be represented by the consequence of an effective exchange of knowledge and skills between physicians who work in the same hospital. In other words, medical teams are multidisciplinary, collaborating and growing together to offer patients the best care pathway according to their needs. This finding is consistent with the *knowledge management* theory, which describes a deliberate process of sharing knowledge, skills and experience within the organisation. Hospital managers must continue encouraging such sharing, as it can be critical to patient survival. Finally, our results suggest that a mechanism of policy reform monitoring is necessary (Iliopoulos and De Witte, 2023). A mechanism for monitoring hospital productivity trends could assist regions in assessing the impact of austerity measures over time.

6. Conclusions

The Italian Healthcare System is constantly evolving. In 2007, some Italian regions reached a very high deficit in healthcare spending, forcing the central government to take action. The RPs were the government's response to the substantial healthcare deficits in certain regions. In this paper, we analysed Italian hospitals' productivity from 2006 to 2018 after the introduction of the RPs. In addition, we investigated the interaction between RPs and the time when a region adopts a specific organisational model. We employed a two-step procedure: first, we calculated productivity using the Malmquist index and solved linear programming problems with DEA; next, we regressed the productivity index and its components on explanatory variables to capture effects of the introduction of the austerity measures, the regional organisational models and specific hospital features.

Our findings indicate that only introducing budget constraints is not enough to improve hospitals' productivity: healthcare staff must be prepared to use all available resources and technologies efficiently. As expected, spending constraints prevented investment in introducing technologies and innovations, although the latter also declined in regions that did not have active RPs. This is a controversial finding, as hospitals not affected by budgetary constraints are expected to continue investing in innovative tools, recognising that they play a crucial role in hospital organisation and patient care. Several innovative tools can support healthcare tracking processes and information sharing between the various actors involved in the patient experience.

Using regression analysis, we found that the interaction effect between the region-centred model and RP periods produced a positive conditional effect on productivity. Another significant result concerns the capital intensity variable: reducing the number of physicians improves productivity and its components. It resulted in regions respecting the constraint on turnover by trying to make the best use of the available resources. The positive effect of this variable on technological change suggested that physicians worked together while maintaining a continuous exchange of information and knowledge to guarantee the most suitable care for patients.

The primary limitation of our study is that we have not included information about healthcare costs, such as expenses for physicians, nurses and other hospital employees, in our analysis. Future studies should investigate other factors that, when integrated with the austerity measures, can improve productivity and its components.

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References

Afonso, G. P., Figueira, J. R., Ferreira, D. C., 2024. Dealing with uncertainty in healthcare performance assessment: a fuzzy network-DEA approach with undesirable outputs. *International Transactions in Operational Research*. https://doi.org/10.1111/itor.13490

Aimone L.G., Alampi, D., Camussi, S. A., Ciaccio, G., Guaitini, P., Lozzi, M., Mancini, A.L., Panicara, E., Paolicelli, M., 2018. La Sanità in Italia: Il Difficile Equilibrio Tra Vincoli Di Bilancio E Qualità Dei Servizi Nelle Regioni in Piano Di Rientro [The Italian Healthcare System: The difficult balance between budget sustainability and the quality of services in regions subject to a financial recovery plan]. Bank of Italy Occasional Paper (427). Bank of Italy, Rome.

Aletras, V., Kontodimopoulos, N., Zagouldoudis, A., Niakas, D., 2007. The short-term effect on technical and scale efficiency of establishing regional health systems and general management in Greek NHS hospitals. *Health Policy* 83, 2-3, 236–245.

Arcà, E., Principe, F., Van Doorslaer, E., 2020. Death by austerity? The impact of cost containment on avoidable mortality in Italy. *Health Economics* 29, 12, 1500–1516.

Armenakis, A. A., Bedeian, A. G., 1999. Organizational change: a review of theory and research in the 1990s. *Journal of Management* 25, 3, 293–315.

Atella, V., Belotti, F., Bojke, C., Castelli, A., Grašič, K., Kopinska, J., Mortari, A.P., Street, A., 2019. How health policy shapes healthcare sector productivity? Evidence from Italy and UK. *Health Policy* 123, 1, 27–36.

Barra, C., Lagravinese, R., Zotti, R., 2022. Exploring hospital efficiency within and between Italian regions: new empirical evidence. *Journal of Productivity Analysis* 57, 3, 269–284.

Blank, J.L., Eggink, E., 2014. The impact of policy on hospital productivity: a time series analysis of Dutch hospitals. *Health Care Management Science* 17, 139–149.

Bordignon, M., Coretti, S., Piacenza, M., Turati, G., 2020. Hardening subnational budget constraints via administrative subordination: The Italian experience of recovery plans in regional health services. *Health Economics* 29, 11, 137

Caves, D.W., Christensen, L.R., Diewert, W.E., 1982. The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica* 50, 6, 1393–1414.

Cavalieri, M., Guccio, C., Lisi, D., Pignataro, G., 2018. Does the extent of per case payment system affect hospital efficiency? Evidence from the Italian NHS. *Public Finance Review* 46, 1, 117–149.

Colombi, R., Martini, G., Vittadini, G., 2017. Determinants of transient and persistent hospital efficiency: The case of Italy. *Health Economics* 26, 5–22.

Dawson, J. F., 2014. Moderation in management research: What, why, when, and how. *Journal of business and psychology* 29, 1, 1–19.

De Nicola, A., Gitto, S., Mancuso, P., 2012. Uncover the predictive structure of healthcare efficiency applying a bootstrapped data envelopment analysis. *Expert Systems with Applications* 39, 12, 10495–10499.

De Nicola, A., Gitto, S., Mancuso, P., Valdmanis, V., 2014. Healthcare reform in Italy: an analysis of efficiency based on non-parametric methods. *The International Journal of Health Planning and Management* 29, 1, e48–e63.

Depalo, D., 2019. The side effects on health of a recovery plan in Italy: A non-parametric bounding approach. *Regional Science and Urban Economics* 78, 103466.

de Nijs, R., Klausen, T.L., 2013. On the expected difference between mean and median. *Electronic Journal of Applied Statistical Analysis* 6, 1, 110-117.

Ding, D.X., 2014. The effect of experience, ownership and focus on productive efficiency: A longitudinal study of US hospitals. *Journal of Operations Management* 32, 1-2, 1–14.

Donaldson, L., 2001. *The Contingency Theory of Organizations*. Sage, Thousand Oaks, CA.

Duque-Uribe, V., Sarache, W., Gutiérrez, E.V., 2019. Sustainable supply chain management practices and sustainable performance in hospitals: a systematic review and integrative framework. *Sustainability* 11, 21, 5949.

Färe, R., Grosskopf, S., Norris, M., Zhang, Z., 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review* 66–83.

Färe, R., Grosskopf, S., Roos, P., 1998. Malmquist productivity indexes: a survey of theory and practice. In *Index numbers: Essays in Honour of Sten Malmquist*. Springer, Dordrecht, pp. 127–190.

Ferré, F., de Belvis, A.G., Valerio, L., Longhi, S., Lazzari, A., Fattore, G., et al., 2014. Italy: Health system review. *Health Systems in Transition* 16, 4, 1–168.

Ferreira, D.C., Marques, R.C, 2016. Should inpatients be adjusted by their complexity and severity for efficiency assessment? Evidence from Portugal. *Health Care Management Science* 19, 43–57.

Franco-Santos, M., Lucianetti, L., Bourne, M., 2012. Contemporary performance measurement systems: A review of their consequences and a framework for research. *Management Accounting Research* 23, 2, 79–119.

Giancotti, M., Sulku, S.N., Pipitone, V., Mauro, M., 2020. Do recovery plans improve public hospitals efficiency and productivity? Evidence from Italy. *International Review of Business Research Papers* 16, 1, 77–98.

Grosskopf, S., Margaritis, D., Valdmanis, V., 2004. Competitive effects on teaching hospitals. *European Journal of Operational Research* 154, 2, 515–525.

Iliopoulos P., De Witte K., 2023. Monitoring and evaluating policy reforms in the EU. DemoTrans Policy Briefs n. 9. https://feb.kuleuven.be/drc/LEER/demotrans/DemoTrans_Policy_Briefs

Karmann, A., Roesel, F., 2017. Hospital policy and productivity–evidence from German states. *Health Economics* 26, 12, 1548–1565.

Kounetas, K., Papathanassopoulos, F., 2013. How efficient are Greek hospitals? A case study using a double bootstrap DEA approach. *European Journal of Health Economics* 14, 979–994.

Lewin, K., 1947. Frontiers in group dynamics. *Human Relations* 1, 5–41.

Liao, H., Wang, B., Li, B., Weyman-Jones, T., 2016. ICT as a general-purpose technology: The productivity of ICT in the United States revisited. *Information Economics and Policy* 36, 10–25.

Mancuso, P., Valdmanis, V.G., 2016. Care appropriateness and health productivity evolution: a non-parametric analysis of the Italian regional health systems. *Applied Health Economics and Health Policy* 14, 595–607.

Mapelli, V., De Stefano, A., Compagnoni, V., Gambino, A., Ceccarelli, A., 2007. I sistemi di governance dei servizi sanitari regionali. *Quaderni Formez*, 57.

Nuti, S., Vola, F., Bonini, A., Vainieri, M., 2016. Making governance work in the health care sector: evidence from a 'natural experiment'in Italy. *Health Economics, Policy and Law* 11, 1, 17–38.

Pederneiras, Y.M., Pereira, M.A., Figueira, J. R., 2023. Are the Portuguese public hospitals sustainable? A triple bottom line hybrid data envelopment analysis approach. *International Transactions in Operational Research* 30, 1, 453–475.

Pereira, M.A., Camanho, A.S., Figueira, J. R., Marques, R.C., 2021a. Incorporating preference information in a range directional composite indicator: The case of Portuguese public hospitals. *European Journal of Operational Research*, 294, 2, 633–650.

Pereira, M.A., Ferreira, D.C., Figueira, J. R., Marques, R.C., 2021b. Measuring the efficiency of the Portuguese public hospitals: A value modelled network data envelopment analysis with simulation. *Expert Systems with Applications*, 181, 115169.

Pilyavsky, A.I., Aaronson, W.E., Bernet, P.M., Rosko, M.D., Valdmanis, V.G., Golubchikov, M.V., 2006. East–west: Does it make a difference to hospital efficiencies in Ukraine? *Health Economics* 15, 11, 1173–1186.

Piubello Orsini, L., Leardini, C., Vernizzi, S., Campedelli, B., 2021. Inefficiency of public hospitals: a multistage data envelopment analysis in an Italian region. *BMC Health Services Research*, 21, 1–15.

Roth, A., Tucker, A. L., Venkataraman, S., Chilingerian, J., 2019. Being on the productivity frontier: Identifying "triple aim performance" hospitals. *Production and Operations Management* 28, 9, 2165–2183.

Simar, L., Wilson, P. W. 2020, Hypothesis testing in nonparametric models of production using multiple sample splits. *Journal of Productivity Analysis* 53, 287–303.

Sommersguter-Reichmann, M., 2000. The impact of the Austrian hospital financing reform on hospital productivity: empirical evidence on efficiency and technology changes using a non-parametric input-based Malmquist approach. *Health Care Management Science* 3, 309–321.

Valdmanis, V., Rosko, M., Mancuso, P., Tavakoli, M., Farrar, S., 2017. Measuring performance change in Scottish hospitals: a Malmquist and times-series approach. *Health Services and Outcomes Research Methodology* 17, 113–126.

World Health Organization, 2019. *Global Spending on Health: A World in Transition* WHO/HIS/HGF/HFWorking Paper/19.4. World Health Organization.