UNIVERSITÀ POLITECNICA DELLE MARCHE
Dipartimento di Scienze Economiche e Sociali

HEALTHCARE EFFICIENCY AND ELDERLY MORTALITY IN ITALY

ROSTAND ARLAND YEBETCHOU TCHOUNKEU
RAFFAELLA SANTOLINI GIULIO PALOMBA
ELVINA MERKAJ

QUADERNI DI RICERCA n. 485

ISSN: 2279–9575

Febbraio 2024

Abstract

The aim of this study is to assess the impact of healthcare efficiency on the mortality rate of elderly people aged 65 and 75 years old and over. To do this, we estimate a dynamic panel data model using the system generalised method of moments (SYS-GMM) on 106 Italian provinces over the period 2012-2019. To measure the efficiency index in the health sector, we apply the Data Envelopment Analysis (DEA) method. We also calculate the index via a bootstrap DEA method for robustness checks.

Our results show that, on average, a 10% increase in healthcare efficiency at the Italian provincial level reduces the mortality rate of older adults by approximately 2% to 3%. Improving healthcare efficiency is crucial in enhancing the health services for the elderly and reduce mortality for this age group. Our findings could be helpful to policymakers in adopting measures that aim to increase healthcare efficiency, taking into account the specific needs of an aging population.

JEL Class.: I10, I18.

Keywords: health efficiency, elderly mortality, DEA, dynamic panel data analysis

Indirizzo: Rostand Arland Yebetchou Tchounkeu (corresponding author), Department of Economics and Social Sciences, Università Politecnica delle Marche, Ancona, Italy. E-mail: r.a.yebetchou@staff.univpm.it.

Raffaella Santolini, Department of Economics and Social Sciences, Università Politecnica delle Marche, Ancona, Italy. E-mail: r.santolini@staff.univpm.it.

Giulio Palomba, Department of Economics and Social Sciences, Università Politecnica delle Marche, Ancona, Italy. E-mail: g.palomba@staff.univpm.it.

Elvina Merkaj, Department of Economics and Social Sciences, Università Politecnica delle Marche, Ancona, Italy. E-mail: e.merkaj@staff.univpm.it.

Healthcare Efficiency and Elderly Mortality in Italy[†]

Rostand Arland Yebetchou Tchounkeu *Raffaella Santolini*
Giulio Palomba *Elvina Merkaj*

1 Introduction

As life expectancy continues to rise globally, the world's population is experiencing a significant increase in the number of older individuals. In 1965, there were 129 million people over the age of 65 world wild; by 2020, this figure surged to almost 750 million people and, according to the United Nations, this number will reach 2.5 billion by 2100 (Scott, 2020). Understanding demographic dynamics is essential to address the health concerns of the elderly and to adopt sustainable health policies, ensuring an affordable economic burden of healthcare for society.

The constant growth of the aging population requires adjustments to healthcare systems to meet the evolving needs of older individuals. One challenge posed by this demographic change is making healthcare system more efficient through the ability of a system to obtain the maximum possible output from a given set of inputs or resources. Technical efficiency in healthcare is defined as maximizing healthcare outcomes, such as the number of patients treated or the quality of care provided, while minimizing inputs, such as costs or resources spent.

Efficient healthcare systems can promptly respond to unprecedented demands, implement timely testing and vaccination campaigns, coordinate public health measures mitigating the impact of pandemics and ultimately save lifes. Becchetti (2023) argues that the ability to best allocate resources and adapt healthcare infrastructure to unprecedented de-

[†]*Declarations of interest: none. Data availability: data will be made available on reasonable request. We are grateful to Mihaela Nicolau for her helpful comments and suggestion.*

mands depends mainly on how population dynamics intersect with healthcare efficiency. This is particularly relevant in pandemic periods such as the recent COVID-19 outbreak (see Lupu and Tiganasu, 2022; Manavgat and Audibert, 2024).

Efficiency in the health sector should be considered along with fairness, ensuring that specific groups, with relatively less capacity to benefit from healthcare services, are not unfairly disadvantaged (Argyris et al., 2022). Elderly individuals often encounter health concerns due to age-related conditions, requiring specialised care. They also face distinct disadvantages in accessing appropriate, affordable, and quality healthcare, despite the introduction of global initiatives, such as Sustainable Development Goal 3, which aims to ensure healthy lives and well-being for everyone at all ages (World Health Organization, 2018). Therefore, studying elderly health within the framework of healthcare efficiency is crucial to identify potential disparities in healthcare supply.

Many countries worldwide have implemented healthcare system reforms to increase efficiency, focusing on optimizing services within fixed budgets. Examples include the creation of 'quasi-markets' for health services or the modification of public reimbursement schemes. The impacts of these reforms are subject of intense debate (see Barbetta et al., 2007). In fact, significant inefficiency persists in the health sector within and between various countries, regardless of income levels. Globally, the World Health Organization estimated that between 20 and 40 percent of total healthcare spending is considered inefficient, equivalent to almost 1.5 trillion US dollars per year.

To the best of our knowledge, there are no studies that investigate the relationship between healthcare efficiency and elderly mortality. We fill this gap by conducting an empirical analysis for Italy. The Italian healthcare system is a relevant case study for two main reasons. First, it is highly decentralised with relevant disparities in its efficiency. Indeed, the quality of healthcare in Italy is found to be uneven between North and South (Lagravinese et al., 2019; Barra et al., 2022), especially regarding human resources and infrastructures (see, for example, De Belvis et al., 2022). Second, Italy is counted among the countries with the oldest population. Becchetti (2023) claims that Italy ranks fifth globally (after Hong Kong, Japan, Switzerland, and Singapore) and is still behind France and Germany in health expenditure-to-GDP ratios, making it difficult to meet the growing demand due to budget constraints and sustainability concerns.

The contribution of our paper is twofold. On the one hand, we aim to evaluate healthcare efficiency using a panel data from 106 Italian provinces[1] over the period 2012 to

[1]In Italy, the healthcare system is organised in three levels: the national government is responsible for

2019. In doing so, we extend the time interval considered by De Nicola et al. (2012, 2014), who measure efficiency at the provincial level in the Italian healthcare system for the years 2004 and 2005. The use of provinces as decision-making units (DMUs) allows us to have a more precise and granular evaluation of health services. Moreover, focusing on local areas where there is homogeneity in terms of population characteristics, healthcare needs, and resource availability, contributes to a more accurate assessment of health efficiency. On the other hand, we investigate whether efficiency in the Italian healthcare system impacts on the mortality of elderly individuals, providing valuable insights that can help policymakers to address healthcare management practices. Our hypothesis is that efficient healthcare systems can allocate resources effectively, directing funding and efforts toward interventions and treatments that have the most significant impact on reducing elderly mortality. Conversely, an inefficient healthcare system creates long waiting lists in health facilities that generate slow services, like monitoring, surveillance, prevention and medical interventions, worsening the health status of individuals, especially of elderly leading to higher mortality rates.

We carry out our analysis estimating a dynamic panel data model with a System Generalised Method of Moments (SYS-GMM) approach (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). The key explanatory variable is an efficiency index that we compute employing both traditional and bootstrap Data Envelopment Analysis (DEA) that yields more robust and reliable scores. Our findings highlight that healthcare efficiency plays a pivotal role in influencing elderly mortality rates, emphasising the significance of well-organised healthcare systems. The impact of effective healthcare is lower for the 75 and older age group due to the higher mortality risk found in this category. These insights have significant policy implications, providing policymakers with valuable guidance for formulating targeted and impactful healthcare policies.

The reminder of the paper proceeds as follows. Section 2 consists of the literature review, while Section 3 illustrates the DEA method we adopt to compute the index of health efficiency. Section 4 is dedicated to the empirical analysis, containing the description of the available data, the definition of the estimated model and the discussion of the results. Finally, Section 5 concludes.

---

resource allocation, financial sustainability, and health policies, while Regions autonomously organize their healthcare systems. Local Health Units provide local health services (*e.g* the primary care, hospitals, and public health initiatives), organised mainly at provincial level.

2 Literature review

Our study is related to two strands of literature. The first deals with healthcare efficiency, whereas the second investigates the impact of healthcare expenditures on various health outcomes.

The literature on healthcare efficiency has experienced a significant growth in recent decades. According to Mbau et al. (2023), several studies focus mostly on the efficiency of specific healthcare facilities such as hospitals and primary healthcare centers. The same tendency is observed also in Italy. For example, Barbetta et al. (2007), examining a group of hospitals in years from 1995 and 2000, discover a decrease in technical efficiency, which they attribute to public policies aimed at reducing hospitalization rates. Daidone and D'Amico (2009) associate the efficiency of health facilities in the Lazio Region to specialization and capitalization. Nuti et al. (2011) identify areas for productivity improvement in the local healthcare system in the Tuscany region. Colombi et al. (2017) examine 133 hospitals and find an average inefficiency score of about 23%.

Less attention is payed to the analyses of healthcare efficiency at territorial level. citetboffardi2022 investigates the healthcare system of the 20 Italian regions from 2001 to 2018 and argues that the quality of institutions directly affects healthcare system activities and indirectly influences people's quality of life. Barra et al. (2022) notice an overall improvement in efficiency of Italian hospitals at regional level from 2006 to 2017, and they find significant differences between northern and southern regions, with the south showing lower efficiency. De Nicola et al. (2014), studying health efficiency at provincial level, conclude that some decentralization from regional governments to local health units could lead to significant improvements. However, too much decentralization might result in deficits in producing healthcare services.

The second strand of the literature related to our study concern the relationship between healthcare spending and health outcomes. Some works in this field document that higher healthcare expenditures are associated to a decrease in avoidable mortality (Heijink et al., 2013), lower infant mortality (Owusu et al., 2021; Sultana et al., 2024), lower maternal mortality (Maruthappu et al., 2015) and an increase in life expectancy (Asiskovitch, 2010). Other contributions aim to analyse whether overall healthcare spending, or some of its specific components, influences population health, often measured by mortality rates. For example, some studies suggest that pharmaceutical spending and public spending have a more pronounced impact on reducing mortality, although results are not uniformly supported across the literature (Gallet and Doucouliagos, 2017). Franzini and Giannoni (2010) assert that Italy is one of the European countries where significant differences in income among regions cause higher health inequalities. According to Quercioli et al. (2012), during 1993-2003, spending on public health services in 19 Italian regions led to a reductions in avoidable mortality rates. Golinelli et al. (2017) also find that spending on "directly provided services" is connected to lower short-term mortality rates in Italy, while other expenses do not show a notable association with mortality rates.

Differently from this last strand of the literature, we propose an analysis that provides a more comprehensive understanding of how healthcare efficiency influences the mortality of older adults. Indeed, efficiency analysis indirectly accounts for health expenditures by considering the inputs used in healthcare facilities, which depend on financial resources. In addition, healthcare efficiency analysis is useful to understand how inputs may be effectively allocated to achieve the desired outputs. This approach provides valuable insights into optimizing resource allocation and promoting cost-effective practices within healthcare systems.

3 Efficiency in the health sector

We measure the efficiency of the health sector in Italian provinces, by applying the DEA method, a nonparametric deterministic approach widely used in the literature. DEA is an approach for evaluating the performance of a set of DMUs in terms of maximizing the efficiency score, defined as the ratio between all available outputs and all usable inputs in a production process. In this context, it is crucial to select a benchmark that consists of a reference scenario that is used to make comparisons. Practically, the benchmark is often associated to the best performing DMUs that represents the so called "best practice frontier" (see Farrell, 1957).

Other methods, such as the Free Disposable Hull (Herrera and Pang, 2005) and the Stochastic Frontier (Barbetta and Turati, 2001), are used in the literature to measure DMU's efficiency. However, we opt for the DEA approach because it identifies best practice frontier without specifying *a priori* the objective function (*e.g.* cost or profit functions). Secondly, it is not necessary specify any weight for inputs and/or ouputs variables because the goal of the DEA approach is to calculate them (Jiang et al., 2020). Moreover, this method does not require assumptions on the distribution of the efficiency scores (see, for instance, Cooper et al., 2011).

We apply the DEA model with input-oriented variable returns to scale, rather than output-oriented variable returns to scale. In practice, we choose to minimise the quantity of inputs required to produce a given amount of output, considering budgetary constraints imposed on Italian public health spending. Following Banker et al. (1984), we compute the Italian provincial efficiency scores (vector $\boldsymbol{\theta}$) by solving the minimisation problem

$$\begin{cases} \min\limits_{\boldsymbol{\lambda},\boldsymbol{\theta}} & \boldsymbol{\theta} - \langle \boldsymbol{S}^{+} + \boldsymbol{S}^{-} \rangle \boldsymbol{\phi}, \\ \text{s.t.} & \boldsymbol{X}\boldsymbol{\lambda}_1 + \boldsymbol{S}^{-} = \langle \boldsymbol{X}_B \rangle \boldsymbol{\theta} \\ & \boldsymbol{Y}\boldsymbol{\lambda}_2 - \boldsymbol{S}^{+} = \boldsymbol{Y}_B \\ & \boldsymbol{\iota}'\boldsymbol{\lambda} = 1, \end{cases} \tag{1}$$

where $\boldsymbol{\theta}$ is a n-dimensional vector containing the health efficiency indices of the Italian provinces, $\langle \boldsymbol{S}^{+} + \boldsymbol{S}^{-} \rangle$ is a diagonal $n \times n$ matrix in which the diagonal is the sum of positive and negative slacks from the benchmark DMU, and $\boldsymbol{\phi} > \mathbf{0}$ is a n-dimensional vector of weights assigned to each province. We correct for slacks in order to overcome the issue of weak efficiency scores (see, for example, Bogetoft and Otto, 2011; Hauner and Kyobe, 2010). To sum up, the objective function of the minimization problem is the difference between the efficiency scores $\theta_i \in [0, 1]$, with $i = 1, 2, \dots, n$, and the weighted sum of slacks.

The $n \times k$ matrix $\boldsymbol{X}$ includes all the inputs, while each column of the $n \times m$ matrix $\boldsymbol{Y}$ correspond to the output variables. Consistently, the n-dimensional square and diagonal matrix $\langle \boldsymbol{X}_B \rangle$ and the $n \times 1$ vector $\boldsymbol{Y}_B$ are the benchmark input matrix and output vector, respectively, while $\boldsymbol{\lambda} = [\boldsymbol{\lambda}_1 \ \boldsymbol{\lambda}_2]'$ is a vector of dimension $k + m$ containing positive weights that, according to the last constraint, must sum up to unity; $\boldsymbol{\iota}$ is a n-dimensional vector of ones. We set as the benchmark DMU the province that reaches the maximum efficiency score.

It is commonly known that the DEA method has several limitations. In finite samples, it does not account for measurement error, making in challenging to distinguish between inefficiency and statistical noise. Since inefficiency is identified by any deviation from the best practice frontier, an estimation bias may occur in this context (see Simar and Wilson, 1998). To overcome this shortcoming, we apply the bootstrap DEA approach that provides more robust and reliable efficiency scores and enhances the accuracy of the analysis. We bootstrap 3000 replications at a 95% confidence interval to obtain the distribution of efficiency scores θ_i ($i = 1, 2, \dots, n$), thus correcting the bias. This is consistent with De Nicola et al. (2012, 2014) and Yebetchou Tchounkeu (2022) that study Italian health sector using a bootstrap procedure.

To calculate the efficiency score it is essential to select relevant inputs and outputs. In doing so, we select inputs and outputs in line with other studies regarding the Italian healthcare system (Levaggi and Zanola, 2004; De Nicola et al., 2012, 2014; Piacenza and Turati, 2014; Boffardi, 2022). In our analysis, we use inputs and outputs related to public and private accredited health institutions. Table 1 shows that inputs include doctors, nurses, and hospital beds, whereas outputs are hospitalization days and turnovers. Figure 1 provides a map of the Italian provinces based on the health sector efficiency index that we calculated for the year 2019. As expected, we observe that efficiency in health sector is higher in the northern part of the country.

Table 1: Input/output variables (848 sample observations)

Variables	mean	std. dev	min	max	description
				inputs	
`doctors`	1163.664	1595.444	23	12 842	number of doctors of public and private accredited health institutions
`nurses`	2534.339	3094.431	25	24 586	number of nurses of public and private accredited health institutions
`hospital beds`	2047.522	2515.365	0	24 371	number of beds of public and private accredited health institutions
				outputs	
`hospedalization days`	580 087.700	739 299.300	0	7 103 905	number of hospitalization days produced by public and private accredited health institutions located within the province
`turnover`	783 415.000	80 544.590	0	1 000 000	frequency of patient hospital bed occupancy in public and private accredited health institutions

Note: the source for data is *Health for All* database (ISTAT).

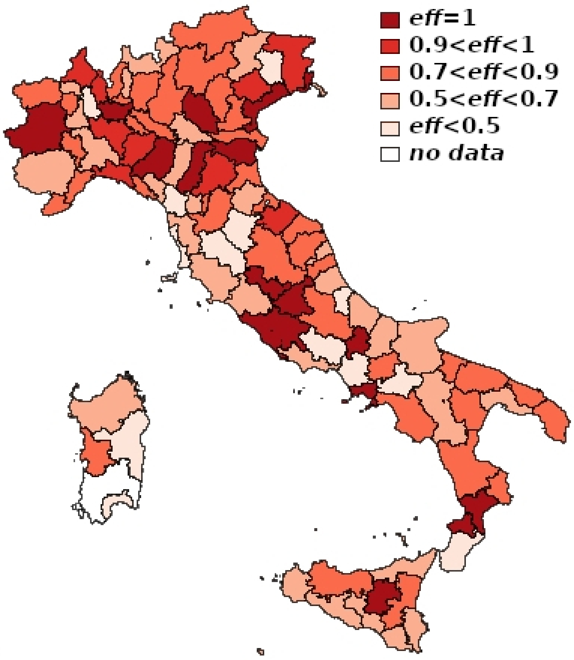
4 Empirical analysis

4.1 Data

Our empirical analysis is conducted on a panel of data concerning 106 Italian provinces,[2] over the period from 2012 to 2019. We excluded the province of Southern Sardinia from the sample because it was established in 2016 and therefore no data is available in the first half of the sample period.

[2]Italy is divided into 107 provinces, representing the medium administrative units between municipalities (lowest local governments) and regions (highest local governments).

Figure 1: Efficiency index of the health sector in Italian province in 2019



Source: Authors' own elaboration.

Table 2 provides an analytical description of all the variables we use in our analysis. Variables `death65` and `death75` represent the mortality rates of elderly people at different age, while `eff` and `beff` are the efficiency scores computed via the standard and the bootstrap DEA models, respectively. The others are control variables that provide insight into the composition of the population within a given area, acting as indicators of healthcare access and quality, and highlighting cultural and behavioral disparities that can influence mortality rates. Specifically, `density`, `foreign` and `fertility` are demographic variables, `gdppc` is an economic variable, whereas `corrupt` is an institutional variable.

4.2 Dynamic panel data model

We study the impact of health sector efficiency on elderly mortality by estimating the dynamic panel data model

$$y_{i,t} = c + \alpha y_{i,t-1} + \gamma \mathtt{eff}_{i,t} + \boldsymbol{x}'_{i,t}\boldsymbol{\beta} + \boldsymbol{\tau}'_t\boldsymbol{\delta} + \mu_i + \varepsilon_{i,t}, \tag{2}$$

Table 2: Variable description and source (848 sample observations)

variable	mean	st.dev.	min	max	description	source
`death65`	1.958	0.306	1.010	2.709	deaths of the population aged 65 and over to the whole population (%)	*ι.Stat* database (ISTAT)
`death75`	1.666	0.282	0.812	2.344	deaths of the population aged 75 and over to the whole population (%)	*ι.Stat* database (ISTAT)
`eff`	0.711	0.196	0.267	1.000	health efficiency scores assessed through DEA. Each score ranges from zero to one, where the unit value is assigned to those public and private accredited health institutions that show the maximum rate of efficiency	Authors' elaboration on *Health for All* database (ISTAT)
`beff`	0.652	0.175	0.244	0.961	health efficiency scores assessed through Bootstrap-DEA. Each score ranges from zero to one, where the unit value is assigned to those public and private accredited health institutions that show the maximum rate of efficiency	Authors' elaboration on *Health for All* database (ISTAT)
`density`	0.270	0.380	0.037	2.838	population density expressed in thousands inhabitants per Km^2	ı.Stat database - ISTAT
`foreign`	7.556	3.436	1.234	17.698	share of foreigners over the total population (%)	ı.Stat database (ISTAT)
`fertility`	1.298	0.121	0.827	1.757	average number of children per woman aged 15-49 years	*Health for All* database (ISTAT)
`gdppc`	10.114	0.276	9.571	10.900	natural logarithm of the per capita Gross Domestic Product (GDP) at provincial level in current market prices (€)	OECD, EUROSTAT
`corrupt`	0.802	0.178	0.000	1.000	control of corruption normalised index. The maximum corruption level is associated to 0	Nifo and Vecchione (2014)

where the dependent variable $y_{i,t}$ is the mortality rate of the elderly for the i-th Italian province at time period t for two categories of individuals, namely population aged 65 and over, and 75 and over. In our setup, the number of provinces is $n = 106$ and the time period is $T = 8$ years. The lagged value $y_{i,t-1}$ enters the equation because the dynamics of the mortality rate of elderly people may exhibit some evolution over time. As we already mentioned, the key-regressor is the variable `eff`, which is the health efficiency index. We consider this variable as endogenous due to its potential association to the elderly mortality rate through a reverse causal relationship. We model the time-invariant unobserved provinces' characteristics via the fixed effects μ_i, and we check for common shocks propagating across provinces by using the yearly dummies $\boldsymbol{\tau}_t$. We have set 2019 as the reference year in order to avoid collinearity. A constant term c and a normally distributed disturbance $\varepsilon_{i,t}$ with zero mean and constant variance also enter the model. Finally, a $n \times k$ vector $\boldsymbol{x}_{i,t}$ containing control variables is also introduced to account for demographic, socio-economic and quality of institutions characteristics (see Table 2).

The dynamic panel data model (2) is estimated with the one-step version of the SYS-GMM estimator (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and

Bond, 1998) since it is more efficient than the first-difference estimator proposed by Anderson and Hsiao (1981, 1982) and have smaller sample bias in finite sample than that resulting from the difference GMM estimator (see Blundell and Bond, 1998; Blundell et al., 2000; Hayakawa, 2007).

We also perform the two-step estimation to obtain efficiency gains (see Bond et al., 2001; Windmeijer, 2005). The SYS-GMM estimator combines equations in first-differences and levels and its consistency depends on the absence of the second-order autocorrelation in the differenced residuals that can be tested via the Arellano and Bond (1991) test. As instrumental variables, we use lagged internal variables in first-differences, for equations in levels, and in levels for equations in first-differences. They are valid instruments if the first-order autocorrelation in the first-differenced error term is different from zero (Blundell and Bond, 2000). The Arellano and Bond (1991) test is suitable also to check wether this condition is satisfied. Finally, we evaluate the validity of all the instrumental variables used in the panel data estimation by using the Hansen J-test for over-identifying restrictions, while we perform the Difference Hansen test to verify the validity of additional instruments used in the SYS-GMM estimates (Arellano and Bover, 1995; Blundell and Bond, 1998, 2000; Bond et al., 2001).

4.3 Results

Table 3 displays the estimation results. We estimated four different models, two for the dependent variable `death65` and two for the dependent variable `death75`, using both one-step and two-step estimation. Furthermore, we conducted a robustness check by replacing the explanatory variable `eff` with `beff` in all models. The estimation is performed using time effects and robust standard errors for heteroskedasticity.

It is worth noting that all models show essentially the same results. As expected, the estimated coefficient of the key variable `eff` is negative and statistically significant. This result indicates that a 10% increase in the provincial health efficiency on average reduces the mortality rate of elderly people by approximatively 2% to 3% (*i.e.*, from 2 to 3 elderly people per 1000 inhabitants). The impact is less as the age of the patients increases. This may occur because people aged 75 and over may experience a higher death rate from natural causes.

Elderly mortality is also significantly affected by demographic characteristics of population such as `density`, `foreign` and `fertility`. Areas with higher population density may have better healthcare infrastructure and resources, thus providing better services and negatively impacting on elderly mortality rates (see columns [1] to [4] in Table 3). Among the control variables, `fertility` can be considered a proxy of people cohesion and unity, enhancing social integration, as documented by Bhandarkar and Shah (2008) and Shah (2008). This cohesion may play a significant role in mitigating elderly mortality rates, emphasizing the importance of social connections. Otherwise, higher shares of foreigners impact positively and significantly on the elderly mortality rate, and this could be due to potential redistribution of financial resources in favour of this population segment that reduces healthcare services destined to other groups like older adults. The variable `gdppc` does not appear to significantly influence the mortality rate. Although per capita GDP is an important indicator of economic development and potentially enhances access to healthcare, its direct impact on mortality rates might be less pronounced. This is attributed to the complexity of health outcomes, along with various other contributing factors. As highlighted by Brenner (2005) rapid economic growth of GDP can even be associated in the short-run with rises in mortality, illustrating the intricate relationship between economic indicators and health outcomes. Our results point out that lower levels of corruption are associated to lower elderly mortality rate. This aligns with Ferrari and Salustri (2020) who argue that health outcomes worsen in more corrupted countries as older adults experience a higher prevalence of chronic diseases. Corruption may also be the responsible for the decline in quality, accessibility, trust of the healthcare service, thus compromising the overall quality of the services offered to citizens, especially the older people.

The diagnostic tests highlight that the estimated model does not contain any relevant misspecification. Indeed, the Arellando-Bond test does not reject the null of second-order correlation in first differences pointing out that the GMM-SYS estimates are consistent. Finally, the Hansen-J-test and the Difference-in-Hansen test indicate that the subsets of instrumental variables used in equations in both levels and first-differences are valid instruments.

5 Concluding remarks

This study focuses on assessing healthcare efficiency at the provincial level in Italy and its impact on elderly mortality. Understanding efficiency at this level enables a detailed evaluation, considering the homogeneity within specific provinces and emphasizing the need

Table 3: GMM-system estimation results

	Estimation output				Robustness check			
	dep. var.: `death65`		dep. var.: `death75`		dep. var.: `death65`		dep. var.: `death75`	
	one-step	two-steps	one-step	two-steps	one-step	two-steps	one-step	two-steps
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
`eff`	−0.307*** (0.106)	−0.300*** (0.107)	−0.234** (0.086)	−0.242** (0.096)	-	-	-	-
`beff`	-	-	-	-	−0.289*** (0.104)	−0.323*** (0.117)	−0.223** (0.086)	−0.253** (0.101)
`density`	−0.646** (0.309)	−0.527* (0.292)	−0.410* (0.218)	0.284 (0.211)	−0.447 (0.280)	−0.330 (0.393)	−0.358 (0.222)	−0.246 (0.247)
`foreign`	0.070 ** (0.034)	0.076 ** (0.032)	0.068 *** (0.028)	0.067 ** (0.027)	0.085 ** (0.037)	0.093 *** (0.036)	0.073 ** (0.029)	0.080 ** (0.033)
`fertility`	−1.354*** (0.392)	−1.319*** (0.414)	−1.163*** (0.301)	−1.082*** (0.345)	−1.341*** (0.381)	−1.279*** (0.419)	−1.137*** (0.305)	−1.053*** (0.352)
`gdppc`	0.389 (0.373)	0.283 (0.384)	0.139 (0.284)	0.070 (0.283)	−0.009 (0.376)	−0.116 (0.429)	0.005 (0.302)	−0.090 (0.298)
`corrupt`	−0.976** (0.391)	−1.041** (0.417)	−0.647*** (0.263)	−0.633** (0.293)	−0.648** (0.277)	−0.604*** (0.206)	−0.544** (0.225)	−0.523*** (0.201)
`death65`(-1)	0.173 *** (0.071)	0.170 ** (0.071)	-	-	0.179 ** (0.070)	0.169 *** (0.062)	-	-
`death75`(-1)	-	-	0.287 *** (0.089)	0.290 *** (0.089)	-	-	0.274 *** (0.087)	0.269 *** (0.088)
`dummy2012`	0.419 *** (0.100)	0.413 *** (0.092)	0.212 *** (0.061)	0.192 *** (0.064)	0.428 *** (0.092)	0.405 *** (0.088)	0.210 *** (0.058)	0.197 *** (0.066)
`dummy2013`	0.156 ** (0.065)	0.149 ** (0.065)	0.105 ** (0.048)	0.087 * (0.051)	0.133 ** (0.057)	0.116 ** (0.059)	0.096 ** (0.045)	0.080 * (0.047)
`dummy2014`	0.088 (0.058)	0.077 (0.060)	0.056 (0.042)	0.041 (0.046)	0.062 (0.056)	0.042 (0.064)	0.044 (0.043)	0.024 (0.044)
`dummy2015`	0.164 *** (0.047)	0.151 *** (0.048)	0.142 *** (0.036)	0.124 *** (0.036)	0.145 *** (0.047)	0.125 ** (0.058)	0.132 *** (0.038)	0.112 *** (0.039)
`dummy2016`	0.066 (0.048)	0.055 (0.052)	0.034 (0.035)	0.018 (0.036)	0.047 (0.046)	0.026 (0.056)	0.027 (0.035)	0.008 (0.036)
`dummy2017`	0.168 *** (0.033)	0.154 *** (0.035)	0.148 *** (0.026)	0.134 *** (0.026)	0.155 *** (0.033)	0.139 *** (0.041)	0.141 *** (0.026)	0.123 *** (0.030)
`dummy2018`	0.050 * (0.029)	0.038 (0.032)	0.025 (0.023)	0.014 (0.023)	0.042 (0.029)	0.029 (0.036)	0.022 (0.023)	0.006 (0.023)
`constant`	−0.030 (3.451)	0.992 (3.501)	1.498 (2.682)	2.062 (2.679)	3.522 (3.448)	4.449 (3.860)	2.686 (2.820)	3.481 (2.883)
Arellano-Bond test for AR(q) in 1st difference:								
$q = 1$	-5.36	-4.80	-5.74	-4.69	-5.00	-4.68	-5.42	-4.56
p-value (z)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$q = 2$	0.43	0.47	0.99	1.00	0.36	0.26	0.95	0.85
p-value (z)	0.636	0.321	0.317	0.257	0.721	0.795	0.341	0.204
Difference-in-Hansen tests of exogeneity of instrument subsets, GMM instruments for levels:								
Hansen test	68.02		74.29		70.94		73.24	
p-value (χ^2_{75})	0.703		0.501		0.612		0.766	
Difference	21.09		14.89		18.55		16.44	
p-value (χ^2_{15})	0.134		0.459		0.235		0.354	
$nT = 848$ sample observations, 105 instruments, $n = 106$ provinces (groups), time effects: YES								

Notes: Standard errors in brackets. ***, ** and * indicate p-values under 1% 5% and 10% respectively.
Instruments for the first difference equation: lagged values of the key-variables (`eff` or `beff`) from the order 2 to the order 11, the 2nd and 3rd order lagged value of the dependent variable. Instruments or levels equation: `corrupt`, the first difference values of both the key regressor (Δ`eff` or Δ`beff`), the dependent variable, and the `constant`.

for targeted interventions to address local inefficiencies and ensure equitable healthcare services across diverse areas.

Our findings reveal a significant negative association between healthcare efficiency and elderly mortality rates. This indicates that effective health systems, characterised by well-organised processes and timely interventions, are suited to meeting the specific needs of elderly patients. Conversely, inefficiencies in healthcare delivery may lead to challenges in providing satisfactory care to older adults, potentially resulting in higher mortality rates within this population group. Thus, improving healthcare efficiency is crucial for enhancing the health outcomes of the elderly, prompting policymakers and healthcare professionals to identify cost-effective interventions and strategies. This emphasizes the importance of targeted interventions and policy measures specifically tailored to address the healthcare requirements of the elderly.

Although our research is conducted in the Italian healthcare context, our findings could also contribute to a broader global discussion on healthcare policies to be implemented taking into account ongoing demographic changes and evolving healthcare challenges.

References

Anderson, T. W. and C. Hsiao (1981). Estimation of dynamic models with error components. *Journal of the American Statistical Association 76*(375), 598–606.

Anderson, T. W. and C. Hsiao (1982). Formulation and estimation of dynamic models using panel data. *Journal of Econometrics 18*(1), 47–82.

Arellano, M. and S. Bond (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The Review of Economic Studies 58*(2), 277–297.

Arellano, M. and O. Bover (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics 68*(1), 29–51.

Argyris, N., Ö. Karsu, and M. Yavuz (2022). Fair resource allocation: Using welfare-based dominance constraints. *European Journal of Operational Research 297*(2), 560–578.

Asiskovitch, S. (2010). Gender and health outcomes: The impact of healthcare systems and their financing on life expectancies of women and men. *Social Science & Medicine 70*(6), 886–895.

Banker, R. D., A. Charnes, and W. W. Cooper (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science 30*(9), 1078–1092.

Barbetta, G. P. and G. Turati (2001). L'analisi dell'efficienza tecnica nel settore della sanità. un'applicazione al caso della Lombardia. *Economia Pubblica 2*, 97–128.

Barbetta, G. P., G. Turati, and A. M. Zago (2007). Behavioral differences between public and private not-for-profit hospitals in the Italian national health service. *Health Economics 16*(1), 75–96.

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

Becchetti, L. (2023). Le sfide del sistema sanitario nazionale. *Recenti Progressi in Medicina 114*(10), 601–604.

Bhandarkar, R. and A. Shah (2008). Association of general population suicide rates with fertility rates: a test of fertility as a measure of social integration. *Psychological Reports 103*(3), 812–818.

Blundell, R. and S. Bond (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics 87*(1), 115–143.

Blundell, R. and S. Bond (2000). GMM estimation with persistent panel data: An application to production functions. *Econometric Reviews 19*(3), 321–340.

Blundell, R., S. Bond, and F. Windmeijer (2000). *Estimation in dynamic panel data models: Improving on the performance of the standard GMM estimator*, Chapter 15 in Baltagi, B. (ed.), Nonstationary Panels, Panel Cointegration, and Dynamic Panels. Advances in Econometrics. JAI Press, Elsevier Science, Amsterdam.

Boffardi, R. (2022). How efficient is the italian health system? Evidence on the role of political-institutional dynamics. *Socio-Economic Planning Sciences 84*, 101388.

Bogetoft, P. and L. Otto (2011). *Benchmarking with DEA, SFA, and R*. Springer Science & Business Media, New York, NY, USA.

Bond, S., A. Hoeffler, and J. Temple (2001). GMM estimation of empirical growth models. Technical report, CEPR Discussion Papers No. 3048.

Brenner, M. H. (2005). Commentary: Economic growth is the basis of mortality rate decline in the 20th century—experience of the United States 1901-2000. *International Journal of Epidemiology 34*(6), 1214–1221.

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

Cooper, W. W., L. M. Seiford, and J. Zhu (2011). *Handbook on Data Envelopment Analysis*. Springer Science & Business Media.

Daidone, S. and F. D'Amico (2009). Technical efficiency, specialization and ownership form: evidences from a pooling of Italian hospitals. *Journal of Productivity Analysis 32*, 203–216.

De Belvis, A. G., M. Meregaglia, A. Morsella, A. Adduci, A. Perilli, F. Cascini, A. Solipaca, G. Fattore, W. Ricciardi, and A. Maresso (2022). Italy: Health system review. *Health Systems in Transition 24*(4), 1–236.

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

Farrell, M. J. (1957). The measurement of production efficiency. *Journal of the Royal Statistics Society series A*(part III), 253 – 281.

Ferrari, L. and F. Salustri (2020). The relationship between corruption and chronic diseases: evidence from europeans aged 50 years and older. *International Journal of Public Health 65*, 345 – 355.

Franzini, L. and M. Giannoni (2010). Determinants of health disparities between Italian regions. *BMC Public Health 10*(1), 1–10.

Gallet, C. A. and H. Doucouliagos (2017). The impact of healthcare spending on health outcomes: A meta-regression analysis. *Social Science & Medicine 179*, 9–17.

Golinelli, D., F. Toscano, A. Bucci, J. Lenzi, M. P. Fantini, N. Nante, and G. Messina (2017). Health expenditure and all-cause mortality in the 'galaxy'of italian regional healthcare systems: a 15-year panel data analysis. *Applied Health Economics and Health Policy 15*, 773–783.

Hauner, D. and A. Kyobe (2010). Determinants of government efficiency. *World Development 38*(11), 1527–1542.

Hayakawa, K. (2007). Small sample bias properties of the system GMM estimator in dynamic panel data models. *Economics Letters 95*(1), 32–38.

Heijink, R., X. Koolman, and G. P. Westert (2013). Spending more money, saving more lives? the relationship between avoidable mortality and healthcare spending in 14 countries. *The European Journal of Health Economics 14*, 527–538.

Herrera, S. and G. Pang (2005). Efficiency of public spending in developing countries: An efficiency frontier approach. *Policy Research Working Papers no. 3645*. World Bank Group eLibrary.

Jiang, J., S. K. Lee, and M. J. Rah (2020). Assessing the research of chines higher education institutions by data envelopment analysis. *Asia Pacific Education Review 21*, 423 – 440.

Lagravinese, R., P. Liberati, and G. Resce (2019). Exploring health outcomes by stochastic multicriteria acceptability analysis: An application to Italian regions. *European Journal of Operational Research 274*(3), 1168–1179.

Levaggi, R. and R. Zanola (2004). Patients' migration across regions: The case of Italy. *Applied Economics 36*(16), 1751–1757.

Lupu, D. and R. Tiganasu (2022). Covid-19 and the efficiency of health systems in europe. *Health Economics Review 12*(1), 1–15.

Manavgat, G. and M. Audibert (2024). Healthcare system efficiency and drivers: Re-evaluation of OECD countries for COVID-19. *SSM - Health Systems 2*, 100003.

Maruthappu, M., K. Ng, C. Williams, R. Atun, P. Agrawal, and T. Zeltner (2015). The association between government healthcare spending and maternal mortality in the European Union, 1981-2010: a retrospective study. *BJOG: An International Journal of Obstetrics & Gynaecology 122*(9), 1216–1224.

Mbau, R., A. Musiega, L. Nyawira, B. Tsofa, A. Mulwa, S. Molyneux, I. Maina, J. Jemutai, C. Normand, K. Hanson, et al. (2023). Analysing the efficiency of health systems: A systematic review of the literature. *Applied Health Economics and Health Policy 21*(2), 205–224.

Nifo, A. and G. Vecchione (2014). Do institutions play a role in skilled migration? The case of Italy. *Regional Studies 48*(10), 1628 – 1649.

Nuti, S., C. Daraio, C. Speroni, and M. Vainieri (2011). Relationships between technical efficiency and the quality and costs of health care in Italy. *International Journal for Quality in Health Care 23*(3), 324–330.

Owusu, P. A., S. A. Sarkodie, and P. A. Pedersen (2021). Relationship between mortality and health care expenditure: Sustainable assessment of health care system. *Plos one 16*(2), e0247413.

Piacenza, M. and G. Turati (2014). Does fiscal discipline towards subnational governments affect citizens' well-being? Evidence on health. *Health Economics 23*(2), 199–224.

Quercioli, C., G. Messina, S. Basu, M. McKee, N. Nante, and D. Stuckler (2012). The effect of healthcare delivery privatisation on avoidable mortality: Longitudinal cross-regional results from Italy, 1993–2003. *Journal of Epidemiology Community Health 67*(2), 132–138.

Scott, A. (2020). Longer, more productive lives will mean big changes to the old rules of aging. Technical report, Finance & Development, IMF. https://www.imf.org/-/media/Files/Publications/Fandd/Article/2020/March/the-future-of-aging-guide-for-policymakers-scott.ashx.

Shah, A. (2008). Association of suicide rates of elderly persons with fertility rates. *Psychological Reports 102*(2), 369–376.

Simar, L. and P. W. Wilson (1998). Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. *Management Science 44*(1), 49–61.

Sultana, S., M. E. Hossain, M. A. Khan, S. M. Saha, M. R. Amin, and M. M. H. Prodhan (2024). Effects of healthcare spending on the public health status: An empirical investigation from Bangladesh. *Heliyon 10*(1), e24268.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics 126*(1), 25–51.

World Health Organization (2018). Health inequalities in old age. Technical report, World Health Organization. https://www.un.org/development/desa/ageing/wp-content/uploads/sites/24/2018/04/Health-Inequalities-in-Old-Age.pdf.

Yebetchou Tchounkeu, R. A. (2022). Public health efficiency and well-being in Italian province. *Quaderni di Ricerca no. 479*. Dipartimento di Scienze Economiche e Sociali, Università Politecnica delle Marche.