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Innovative Applications of O.R.

Efficiency of the medical care industry: Evidence from the Italian regional system

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ABSTRACT

What might be the relation between clinical research and efficiency of medical care suppliers? Is the hypothesis of a positive relation consistent? Considering efficiency as the supplier's ability to maximize the number of patients hospitalized in a mobility process among regions (i.e. mobility balance), this work aims at highlighting the existence of a positive externality of pharmaceutical clinical research on that kind of efficiency. In other words, an externality is able to affect the patients' perception of good/bad quality of outputs supplied by the medical care industry, leading their mobility process. Taking Italy and the mobility of patients among regions into account, an Operational Research study will be performed in order to support this assumption.

The goal of this work is to show an alternative way to increase the efficiency of medical care suppliers on the market of health care, that is to say, through their competitiveness on the market of human experimentation.

1. Introduction and literature review on health OR

When analyzing national health care systems, one of the main characteristics that are taken into account concerns the patients' access and, of course, their ageing process can only make this issue even more pertinent in the political debate. On the one hand, in any social state, there is the necessity to guarantee health care for all those who need it but, at the same time, there are constraints linked to the national budget, as well as interest in not placing the entire burden on future generations. On the other hand, given this budget constraint, it is necessary to guarantee the efficiency of the health care systems, i.e. the appropriateness of diagnosis and the effectiveness of treatment.

Several solutions have been adopted by administrations in order to increase the efficiency of the health care system, but this is still an open issue, especially after the financial crisis at the beginning of the 21st century. Considering the patients' perception of quality of health care outputs, this paper tries to provide an innovative way to achieve this efficiency, that is to say, through the supply of an unusual service: pharmaceutical clinical research.

Clinical research is a specific phase of the pharmaceutical industry in which candidate drugs are tested on patients to collect data on safety and effectiveness. Ippoliti (2010) suggests the existence of a market in which pharmaceutical innovation is exchanged for information, i.e. clinical evidence on experimental medical treatments. A market where the main actors involved in this exchange process are pharmaceutical companies, patients (i.e. research subjects) and physicians (i.e. medical researchers). Considering Italy, research subjects can represent a regional resource on this market of human experimentation but, at the same time, these patients could perceive pharmaceutical clinical research as an efficiency factor of the regional supply of health care.

Imagining no barriers to accessing each regional supply of medical care, the natural consequence will be the patients' mobility towards those regions that are more competitive on the market of human experimentation, i.e. where the innovation in pharmaceutical knowledge is higher. This is precisely the innovation suggested by this paper: treating human experimentation as a potential service able to affect the efficiency of the regional medical care industry. The proposed issue is analyzed through an Operational Research study (OR), supporting the proposed correlation between pharmaceutical clinical research and the efficiency of the regional industry.

Royston (1998) suggests several potential areas for health OR applications, whereas Vissers (1998) defines the level of the decision making process at which the process and operations take place. Starting from their analysis on areas and levels, Brailsford and Vissers (2011) identify nine potential stages of development for three main levels and use this classification to report on the development of OR in health care, analyzing the papers presented at ORAHS meetings over the 35 years of its existence. Referring to the suggested structure, the proposed OR study can be easily placed at regional level, between the first and the second life cycle

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stage, i.e. between *identifying consumer requirements* and *developing a new service*.

According to Brailsford and Vissers (2011), that specific life cycle is not a particularly active area of OR, since other disciplines, such as Marketing and Psychology, are more likely to be involved in that field. In this cycle there are OR studies on care for the elderly (e.g. Lagergren, 2005; Forte and Bowen, 2005), as well as on intermediate services (e.g. Bowen et al., 2005; Roe and Beech, 2005). However, the authors also suggest that this could be an interesting area for OR, as involvement with starting up an innovation creates many follow-up opportunities for OR contributions and there is clearly scope for further work in this area, using methodologies which enable different (and possibly conflicting) stakeholder viewpoints. Taking this perspective into account, this paper is able to increase the current knowledge on health OR as well as to stimulate an in-depth debate about the opportunities of pharmaceutical clinical research. A debate that can only be heated, since the potential risks and ethical issues linked to the testing phase in the pharmaceutical industry, will lead to conflicting, but interesting, public stakeholder viewpoints.

The main methodology applied in this paper is the Data Envelopment Analysis (DEA). According to Cook and Seiford (2009), the DEA approach is a non-parametric technique which allows us to measure, by solving a linear programming system, the performance of a subject and to assign to it a score representing its efficiency performance. This technique has been applied in many contexts to study relevant problems in the OR field, e.g.: in the insurance industry (Barros et al., 2010); bank and credit risk applications (Staub et al., 2010; Fethi and Pasiouras, 2010; Ray and Das, 2010); the container ports (Hung et al., 2010); the energy and environmental field (Zhou et al., 2008) and, obviously, in the medical care field (Dlouhy et al., 2007; Chang et al., 2004; Cheng et al., 2005). However, considering the analysis proposed in this work about how a specific service could affect the perceived quality of patients, the authors will go beyond the DEA approach, applying the second stage suggested by Simar and Wilson (2007).

The next section describes the decision making process of patients and their mobility towards the most efficient medical care industry. In the third section the OR study is proposed, following the two-stage procedure suggested by Simar and Wilson (2007). In the first stage, the Data Envelopment Analysis (DEA) output-oriented procedure with bootstrap is used to estimate the efficiency of each regional medical care industry; whereas in the second stage the regression analysis aims at showing correlations between efficiency scores and some key explanatory variables. According to the proposed theory, the patients' positive mobility will be used as output in the DEA methodology, whereas the variables representing the effort made by the regional systems will be used as inputs.

According to results of the OR, the conclusions deal with implications of public policy and the potential debate about the opportunities of pharmaceutical clinical research. The paper will propose a public policy aimed at increasing the efficiency of the regional industry through this specific service, that is to say, the competitiveness of these medical care industries on the market of human experimentation.

2. The decision making process of patients

Patients have to face a choice among potential suppliers of health care and then, after that choice, among several medical treatments proposed by the selected supplier. According to Simon (1947), people could be affected by bounded rationality and, therefore, they could be forced to make choices through some short-cuts, i.e. some heuristic approaches for their decision making process, but saving time and energy. Considering the choice among treatments, one of this heuristic approaches might be trusting a person and thus initiating a delegation process towards that subject, as suggested by Arrow (1963). In other words, there is not a choice among treatments but only an acceptation of what a subject is suggesting.

According to Rotter (1967), Rousseau et al. (1998) and Six (2005), trust is based on the expectation that the other will perform something for you. Taking health care into account, the patients' expectations could relate to their good health status. Moreover, according to Rotenberg (1991, 1994, 2001), trust can have both a cognitive and a behavioral dimension. Referring again to our background, the former is given by the belief a patient might have about the physician (i.e. his/her reputation), whereas the latter is affected by the approach of that physician to the clinical case, to confirm or eliminate a previous good/bad belief. Finally, according to Lewicki and Bunker (1995, 1996), one of the sequences in their trust-building model relies on knowledge, i.e. on the information acquired through communicative interactions. Taking the physician-patient relationship into consideration, this means that the informed consent session and the diagnostic one might be the keys of the trust process and of the delegation mechanism behind it.

However, what are the consequences of this process? In other words, which might be the consequence of a negative response into the validation process? Alternatively, without a center with good reputation nearby, what might the patient do?

2.1. Patients and mobility process

According to the proposed theory, patients are affected by a cognitive and a behavioral process. There is a good reputation that might, or not, be validated by the physicians' actions and/or other workers of the medical center. Without that positive response in the validation process or a bad previous image, a mobility process will start towards a better medical center.

Taking Italy into account, Table 1 tries to empirically support this simple, but significant, relation between the proposed decision making process of patients and their mobility. Both models are multiple regressions but in column 1 the fixed effect option has been applied, whereas in column 2 the random effects option is used. Moreover, the number of hospitalizations (acute) is considered an analytical weight in the first column to detect the degree of this negative impact on the patients' perception. Data are extracted from the annual report of the Italian Ministry of Health on regional hospital activity (SDO).

Column 1 suggests that a bad discharge, such as the patient's death, has a negative impact on positive mobility in a region. In other words, the failure of a medical center's activity negatively affects the number of patients that come from another region to be treated. This is a clear example of bad reputation that can

Table 1
Hospitalization (acute) in Italy between 2005 and 2007 (cross-sectional time-series regression model).

Variables	(1) Positive mobility	(2) Negative mobility
Discharged dead (patients)	−0.274[a]	
	(0.101)	
Discharged voluntary (patients)		0.155[b]
		(0.0631)
Constant	51,012[a]	25,748[a]
	(1,567)	(3,045)
R-squared	0.8459	0.6155
Number of observations	63	63
Number of regions	21	21

Standard errors in parentheses.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.1$.

prevent the patients' mobility. On the other hand, column 2 supports the same idea of patients' mobility through another kind of discharge, i.e. voluntary. Assuming a negative response into the validation process, patients will be voluntarily discharged from the medical center to perform mobility towards another one (i.e. negative mobility). What can affect this validation process? Within the decision making process, which aspects of a physician's performance can positively affect a good previous reputation?

Among several factors, one of the most interesting is the pharmaceutical clinical research, since it is a specific medical activity in which the physician can exert maximum effort in communicative interaction. At the same time, this process is the easiest way for the management of a medical facility to increase the perceived quality of their center and, consequently, its competitiveness on the national medical care market.

2.2. Human experimentation and patients

Pharmaceutical clinical research is the testing phase of companies' candidate drugs on patients in order to collect data about safety and effectiveness. This activity is risky since the final outcome can only be estimated – i.e. there can be potential unexpected adverse events and, therefore, *uncertain* expected effectiveness. Physicians are involved in this activity as medical researchers, whereas patients are enrolled as research subjects. Considering risks and relative uncertainty, physicians will spend time and energy emphasizing the patients' expectations in terms of good outcome in order to enroll them in the experimental activity. According to the *Prospect Theory*, as suggested by Kahneman and Tversky (1979), this emphasizing strategy is also known as framing strategy: a choice might be affected by the specific framing strategy implemented by someone to stimulate a certain decision. According to Sankar (2004), this strategy has been successfully applied to human experimentation by physicians in order to persuade patients to enroll. In other words, the framing strategy can positively affect the patients' perception of the expected outcome of the proposed experimental treatment.

According to the suggested background, there could be a positive correlation between human experimentation and the validation process of patients' belief. This is exactly the main aim of this work: to give empirical support to the proposed correlation between the patients' belief and the physicians' approach to the clinical case, seen as a validation process of a good previous belief. This could be a great opportunity to develop this kind of service into the medical care industries with this specific target: enforcing the patients' trust.

Starting from that decisional process and taking Italy into account, the next section will develop an OR aimed at supporting the main result of this work: the (positive) role of pharmaceutical clinical research in the patients' mobility process. Obviously, in order to increase the predictability of the proposed model, other factors that might affect the patients' decision making process will be considered, such as political influence, the complexity of medical treatments and the degree of public sector services within the medical facility.

3. Methodology and results

According to the devolution of power to the Regions (2001),[2] the Italian health care system is organized in regional systems, that is to say, there are 21 regional medical care suppliers.[3] Taking strongly balanced panel data into account, from 2002 to 2006, the OR will consider these regional suppliers as observations. In other words, each regional system will be considered as a supplier on the national medical care market. According to the theory proposed in the previous section, the patients will move towards the supplier with a reputation perceived as better.

This paper takes a single regional industry into account. This means that this work considers an individual body able to supply medical treatment to patients that is composed of both private and public institutions, as well as both standard hospitals and medical centers with high specialization. Moreover, this work assumes that the main target of each regional industry is the maximization of the perceived quality of these treatments and therefore, in relation to patients' mobility, the positive balance of this process. Indeed, according to the agreement among Italian regions about compensating interregional patient mobility (2010).[4] the negative mobility is a cost for the regional medical care industry. In details, each Italian region receives a per capita income by the central government and then reimburses the medical treatments to the medical centers. This means that it is necessary to compensate those facilities that have supplied needed medical treatments in another region. For this specific reason, if an industry with economy of scale is envisaged, the paper assumes that perceived quality is the main target of these regional industries in order to achieve, at least, a non negative balance.[5]

The choice of a national background, instead of an international one, is affected by data availability as well as the necessity to respect a linguistic constraint that could prevent the mobility.

In next two sections the applied two-stage procedure and results will be shown.

3.1. Efficiency and productivity

This section explains the approach used for computing technical efficiency, and it presents some descriptive statistics about data and results.

In line with Simar–Wilson (Simar and Wilson, 2007), a two-stage procedure for assigning efficiency scores to regional medical care suppliers and for investigating the determinants of obtained results has been applied. On the one hand, technical efficiency scores have been computed through the Data Envelopment Analysis (DEA) with bootstrap procedure.[6] On the other hand, technical efficiency scores become implicit variables in a random effects model and in a truncated regression one, whereas the regressors should explain the differences in regional medical care industries.

The reference procedure was proposed in 2007 by Simar–Wilson to eliminate endogeneity problems in DEA computation. Even if in the second stage these authors propose the truncated regression methodology to introduce environmental variables, in this study, taking a panel data into account, the random effects model appears to be more suitable. However, to be coherent with the proposed bibliography, both models are presented. Moreover, Malmquist's productivity indexes have been computed to investigate changes in efficiency performance of regional medical care systems.

[2] One of the four amendments to the constitution, approved during the Italian thirteenth legislature, concerns the regional competence in the health care system. According to this constitutional reform, the national competence is the establishment of *essential levels of care*, whereas the regional competence is the *organization and supply* of medical treatments.

[3] This work takes into account 19 Italian regions and 2 Autonomous Provinces (i.e. Trento and Bolzano).

[4] For an in-depth analysis, the reader can see the unified code of the Italian Conference of Regions and Autonomous Provinces, protocol number 10/040/CR4/C7, 06.05.2010.

[5] According to Carlton and Perloff (2005), we are assuming that the marginal cost of supplying a medical treatment is lower than the average one. This assumption is reasonable if the reader considers the huge fixed costs of each health care system.

[6] For a complete description of the bootstrapping procedure, see Simar and Wilson (1998, 2000, 2007).

The Data Envelopment Analysis (DEA) approach does not require a specified distribution form and, on the basis of the DEA efficiency scores, it is possible to sort medical care suppliers. The proposed methodology is deterministic and it does not consider the error component that is directly imputed to inefficiency. To compute the productivity indexes of medical care systems Malmquist's indexes (Malmquist, 1953; Simar and Wilson, 1999) have been used. They present some advantages in comparison to other productivity measures and give the opportunity to build an aggregated index of productivity considering more inputs and outputs, similarly to the DEA methodology.

3.1.1. Data Envelopment Analysis

In the first stage, following the Simar–Wilson procedure (2007) the DEA technique has been used with the aim of assigning technical efficiency scores to each medical care supplier (*TE*). A comprehensive description of this approach is presented by Charnes et al. (1978), Färe et al. (1994) and Coelli et al. (1998).

The DEA approach allows us to build a deterministic non-parametric production frontier comparing the performances of several Decision Making Units (DMUs, which in this study are regional medical care industries). Technical efficiency scores are calculated on the basis of the radial distance of the subjects to the frontier.

The approach can be input or output oriented. In the input-oriented approach, the output levels do not change, whereas the input quantities are reduced proportionately until the frontier is reached. This orientation is often adopted when the decision maker can control inputs but not outputs. Alternatively, the output-oriented framework aims at maximizing the output levels keeping the inputs constant. This orientation is also known as the output-augmenting'' approach; indeed, it keeps the input bundle unchanged and expands the output level until the frontier is reached (Daraio and Simar, 2007). In this work the output orientation has been preferred because the inputs used cannot be easily changed. Indeed, the management of resources is not flexible in these regional industries, especially taking the short term and the political consensus into account. In other words, the hypothesis of significantly cutting down the number of beds, as well as the number of workers, is not easily viable and politically acceptable.

On the basis of the previous considerations, the output-oriented model has been used, as proposed by Farrell Michael (1957), and variable returns to scale (VRS) have been implemented (Banker Raijiv et al., 1984).

The technical efficiency scores (TE_i) connected to each regional medical care supplier (Data Making Unit, DMU) are computed in this way:

$$TE_i = z_i \; i = 1, \ldots, n$$

where n is the number of DMUs and $1 \leqslant TE_i \leqslant +\infty$.

TE_i scores are computed by solving the following linear programming duality problem, on the basis of output-oriented DEA approach (Farrell Michael, 1957):

$$\begin{aligned} &\mathrm{Max}_{z,\lambda} \quad z_i \\ &\text{subject to}: N1'\lambda = 1 \\ &\qquad zy_i - Y\lambda \leqslant 0 \\ &\qquad -x_i + X\lambda \leqslant 0 \\ &\qquad \lambda \geqslant 0 \end{aligned}$$

where z is a scalar > 1, λ is a vector of nx1 weights allowing for convex combination of inputs and outputs, Y is an sxn output matrix, X is an input matrix and N1 is an Nx1 unitary vector. Furthermore, $z - 1$ indicates the output proportional increment, maintaining the input level constant.

According to Simar and Wilson (2007), a bootstrap procedure has been applied to the DEA approach to correct the score values and their confidence intervals, refined by the bias.

Efficient medical care suppliers display a technical score equal to 1 and this means that the considered subject is on the frontier, that is to say when the TE score increases technical efficiency decreases.

As described in the second section, the output of the model is represented by the active mobility of the patients, that is to say the output of this efficiency is the patients' immigration to a given region to receive appropriate medical treatment. The input variables introduced in the DEA for the computation of TE scores are all factors that might affect the supply of medical treatments: physicians, nurses, technicians, and beds. Moreover, to correctly balance the proposed output, the passive mobility of patients has been considered as input (i.e., the patients' emigration from their region), while the regional population represents a dimensional variable of the local market. As mentioned above, the negative mobility is an added cost to the regional medical care industry and, therefore, it is treated as in input.

Table 2 shows descriptive statistics of the obtained efficiency scores, as well as the adopted output and inputs. The data about physicians, nurses, technicians, beds and population are extracted from the database of the Italian National Statistical Institute (ISTAT), whereas the data about patient emigration and immigration are extracted from the annual report of the Italian Ministry of Health on regional hospital activity (SDO).

In details, taking mobility into account, this paper considers all the hospitalizations (critical phase) performed by regional medical care industries. In other words, this work considers all the medical treatments provided by these industries to patients (immigrated) through their hospitalization in all the critical phases. Obviously, what is a positive mobility (emigration) for a region is negative (immigration) for another region. Moreover, the beds considered in the analysis are all potential beds assigned to hospitalization (critical phase).

According to the ISTAT classification, the sample analyzed can be classified in five geographical areas: North-west, North-east, Centre, South and Islands. Table 3 provides a descriptive statistic of these areas with respect to the mobility process of the patients. This table clearly shows that the patients' perception of their regional system in the South Italy (i.e. Islands and South) is negative, hence the emigration is higher than the immigration. At the same time, it is clear that a better quality of the medical care industry is perceived in the North Italy. Obviously, in this table the population is considered as an analytical weight to obtain a proper comparison among the observations.

Table 4 presents the descriptive statistics of efficiency scores with respect to the geographical areas. These scores represent the abovementioned patients' mobility considering all the resources necessary to supply the required medical treatments. This table suggests a prospective that is very far from what said above, especially for what concerns the Center of Italy. An interpretation of this result could be linked to the resources adopted by the regional systems. In other words, the human and technical capital invested in the North of Italy might be very much higher than the capital invested by the best supplier.

This result might be perfectly in line with the proposed thesis. A higher number of human resources, as well as beds, might be the key to guaranteeing access to the medical treatment, minimizing the waiting list and therefore obtaining a higher level of active mobility, even if the process is not the most efficient. At the same time, another factor should be considered: the mobility cost. On the one hand, taking the patients' means into account, if the South of Italy is the worst place to receive care and patients do not have enough money to move towards the best perceived industry, they

Table 2
Descriptive statistics of efficiency scores, output and inputs (mean on 2002–2006).

Variable	Obs	Mean	Std. dev.	Min	Max
Eff. scores	105	2.279284	1.349049	1.199548	6.646117
Population	105	2766533	2342251	120228	9510322
Physicians	105	5706.69	5094.72	210	20389
Technicians	105	1703.91	1520.92	103	6779
Nurses	105	12638.68	11056.41	476	46733
Beds	105	9584.58	7995.33	416	34738
Emigration	105	29563.15	29599.74	1295	138567
Immigration	105	28189.68	17935.68	3086	71871

Table 3
Descriptive statistics of patients' mobility concerning macro areas (mean on 2002–2006).

Area	Mean	Std. dev.	Freq.	Obs
Islands	−27952.968	13264.391	33228556	10
South	−29710.906	18543.727	70131307	30
Center	15229.333	9139.0488	55898281	20
North-east	25406.529	16029.016	54704994	25
North-west	43086.587	41138.456	76522807	20
Total	8694.9568	38468.72	2.905e+08	105

Table 4
Descriptive statistics of efficiency scores concerning macro areas (mean on 2002–2006).

Area	Mean	Std. dev.	Freq.
Island	5.515936	.66398202	10
South	2.4428102	1.135831	30
Center	1.5613774	.31372946	20
North-east	1.8004458	.71195839	25
North-west	1.7321221	.57434807	20
Total	2.2792838	1.3490492	105

will choose the second best, that is to say the cheapest, although not the best, solution. On the other hand, patients with adequate means will choose their first best, that is to say they will go where the perception of professionalism and effectiveness of the proposed treatment is higher.

3.1.2. Malmquist productivity indexes analysis

In this section Malmquist indexes have been computed. The main idea of the Malmaquist indexes is to compute the ratio between outputs and inputs, considering changes in time.

As suggested by Färe and Grosskopf (1996), supposing to have data on a single input (x) and output (y) at two periods (t and $t+1$) the Total Factor Productivity (TFP) is defined as:

$$TFP = \frac{y^{t+1}/x^{t+1}}{y^t/x^t}.$$

It is possible to define how the Malmquist index of productivity changes, in the following manner:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{\frac{0c}{0a}}{\frac{0f}{0b}} \cdot \frac{\frac{0c}{0d}}{\frac{0f}{0e}}\right)^{1/2} = \left(\frac{\frac{y_{t+1}}{f_{t+1}(x_{t+1})}}{\frac{y_t}{f_{t+1}(x_t)}} \cdot \frac{\frac{y_{t+1}}{f_t(x_{t+1})}}{\frac{y_t}{f_t(x_t)}}\right)^{1/2}$$
$$= \underbrace{\left(\frac{y_{t+1}}{f_{t+1}(x_{t+1})} \cdot \frac{f_t(x_t)}{y_t}\right)}_{\text{Change in Efficiency } (eff)} \cdot \underbrace{\left(\frac{f_{t+1}(x_{t+1})}{f_t(x_{t+1})} \cdot \frac{f_{t+1}(x_t)}{f_t(x_t)}\right)^{1/2}}_{\text{Technical Change } (tech)}$$
$$= \underbrace{\left(\frac{0c}{0a} \cdot \frac{0e}{0f}\right)}_{\text{Change in Efficiency } (eff)} \cdot \underbrace{\left(\frac{0a}{0d} \cdot \frac{0b}{0e}\right)^{1/2}}_{\text{Change in Efficiency } (tech)}$$

Values of Malmquist index bigger than 1 represent improvements in productivity.

In its final composition, the Malmquist index is composed of two indexes built as distance ratios, where the expression in the first parentheses measures the change in efficiency between period t and $t+1$. This term is referred to as *Efficiency Change* or *Change in Efficiency* (*eff*). The square root of the second parenthetic expression captures shifts in the frontier of technology and is referred to as the *Technical Change* (*tech*) component.

Change in efficiency measures the position of the kth medical care supplier in the input–output space at time $t+1$ in relation to technologies at times t and $t+1$. This ratio gives a measure of the shift in technology relative to the position of the kth medical care supplier at time $t+1$ (Wheelock David and Wilson Paul, 1999). Values of *eff* greater than 1 indicate increases in efficiency, while values lower than 1 indicate decreases in efficiency.

Technical change measures the position of the kth medical care supplier in the input–output space at time t in relation to technologies at times t and $t+1$. It gives a measure of the shift in technology relative to the position of the kth medical care supplier at time t (Wheelock David and Wilson Paul, 1999).

Values of *tech* greater than 1 indicate improvements in technology, while values lower than 1 indicate technical regress.

At this point it is clear that *Total Factor Productivity* (*tfp*) between t and $t+1$ is given by the product of Change in efficiency and Technology change:

$$tfp_{t,t+1} = M_{t,t+1} = eff_{t,t+1} \cdot tech_{t,t+1}.$$

The problem of computing *tfp* lies in the determination of technology because it can be only an approximation. Hence, DEA frontiers have been built as proposed by Coelli et al. (1998), Cooper William et al. (2007).

The approach used for computing the DEA frontier is output-oriented; then the DEA score represents the increase in output necessary to achieve full efficiency.[7]

In Table 5 there are statistics on the Malmquist indexes (*tfp*) and their decomposition in change in efficiency (*eff*) and technology change (*tech*) for the 2002–2006 period. For each geographical area the Malmquist productivity has decreased more or less with the same impact. Not only, also the components change in efficiency (*eff*) and change in technology (*tech*) have decreased in the considered period, except for technology change in the North-eastern area. Nevertheless, the most relevant information derives from the analysis of efficiency components because the results suggest that medical care suppliers were not able to improve their efficiency between 2002 and 2006. This means that medical care suppliers changed their position in relation to the frontier in 2006 but the distance to this new frontier was bigger than that existing in 2002, that is to say that medical care suppliers have not used their inputs efficiently.

The second step of this OR deals with the regression analysis, i.e. it shows the correlations between efficiency scores and the key

[7] The computation of the Malmquist indexes starting from the DEA approach is exhaustively explained in Coelli (1996).

Table 5
Descriptive statistics of Malmquist indexes concerning macro areas (geometrical mean on 2002–2006).

Area	Mean (Malmquist indexes)	Mean (eff)	Mean (tech)	Freq.
Islands	0.84593	0.92228	0.91721	2
South	0.83044	0.89301	0.92993	6
Center	0.82363	0.85683	0.96125	4
North-east	0.88825	0.88697	1.00144	5
North-west	0.82043	0.84008	0.97662	4
Total	0.84207	0.87703	0.96014	21
Standard deviation	0.11749	0.12362	0.05273	
Minimum value	0.61804	0.70622	0.87239	
Maximum value	1.02985	1.07900	1.05353	
Values > 1	14.29%	19.05%	28.57%	

explanatory variable, as well as some control variables. The former step of this analysis focused on the industries' ability to maximize their target (patients' immigration), taking some key resources into account, whereas the next step will try to highlight what might affect their maximization process. In other words, the next section describes the results deriving from the regression analyses and it will explain how the reputation of these industries might be supported.

3.2. Results

The Simar–Wilson procedure (2007) suggests using truncated regression after having estimated efficiency scores through the DEA approach. However, since in this work a panel data is considered, also a regression model with random effects is run.

According to the second section, the patients are able to perceive the quality of medical care suppliers. This might be due to a previous personal experience or to remarks by someone close to the patients. A perception mechanism is linked to the reputation of these regional industries. But, what affects this reputation?

Table 6 tries to give an answer to this question, stressing some of the key factors that might affect the suppliers' reputation. A cross-sectional time-series regression model with random-effects option (within regression estimator) has been applied. The option is coherent with the idea that the sample of observations (Italian regions) can be considered a random extraction from a population (European regions). Column 2 uses the same model but applying the bootstrap option with 200 replications.

In both models, if all the regression coefficients in the fitted model are zero, the statistic tests are jointly zero and thus the hypothesis is rejected. Moreover, the squares of the multiple correlation coefficients (R-sq) are good. The model shows that 78% of the variance of the Efficiency scores is accounted for by the eight explanatory variables of interest. Whereas, taking *pairwise* correlation coefficients between the explanatory variables into account, acceptable values with high significance level have been obtained. Finally, it has been tested that the error terms are independently normally distributed with zero mean and constant variance.

As in the previous analysis, five dummy variables are considered to identify the geographical area of these regional industries. These variables should describe the heterogeneity of workers, as well as the medical institutions in which they are working. The idea is that a regional industry in the South of Italy is different from one in the North of Italy. This might depend on traditions and/or values that can positively or negatively affect the performance of these workers and therefore the medical care they supply. This is a well-known phenomenon that affects the South of Italy and patients' health status is not saved.

The political influence is a negative factor for the industries' reputation, that is to say the political appointment in medical institutions can have a negative impact on the quality of the medical treatments. In order to understand this effect, a dummy variable is considered (Political Change).[8] Taking regional elections into account, this variable considers if the regional government has changed or not, independently of its political alignment. Obviously, the effect is considered in the years after the election.

Table 6
Relation between efficiency scores and key factors (cross-sectional time-series regression model with random-effects option).

Variables	(1) Efficiency scores	(2) Efficiency scores
North-west	−3.954[a]	−3.954[a]
	(0.757)	(0.393)
North-east	−3.790[a]	−3.790[a]
	(0.704)	(0.312)
Center	−3.961[a]	−3.961[a]
	(0.707)	(0.295)
South	−3.101[a]	−3.101[a]
	(0.618)	(0.169)
Political Change	0.269[b]	0.269[b]
	(0.112)	(0.136)
Clinical Research	−0.296[a]	−0.296[a]
	(0.115)	(0.119)
Case Mix Index	3.360[c]	3.360[c]
	(1.774)	(1.661)
Public	−3.955[a]	−3.955[a]
	(1.192)	(1.477)
Constant	1.037	1.037
	(1.775)	(1.719)
F statistic (*p* value > *F*)		
Prob > *F*	0.0000	0.0000
Observations	102	102
Number of regions	21	21
R-squared		
Within	0.2164	0.2164
Between	0.7845	0.7845
Overall	0.7655	0.7655

Standard errors in parentheses.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.1$.

The result supports the goodness of the proposed hypothesis, i.e. political change negatively affects efficiency. Political change might provoke general malcontent since the new appointments, of both managers and top clinicians, are a consequence of political choices instead of meritocracy and professionalism. The workers' discontent affects the quality of medical treatments and industry's reputation, thus influencing the patients' perception.

There is also another interesting aspect of patients' mobility. Is the patients' mobility affected by the necessity to receive special treatment? In other words, is patients' mobility the consequence of a lower complexity of the performed medical treatments? The Case Mix Index catches this effect. This index is proposed by the Italian Ministry of Health to represent the complexity of regional hospitalizations in comparison to the average.[9] A value higher than 1 represents a complexity higher than the average whereas a value lower than 1 represents a complexity lower than the average. If the mobility were affected by this complexity, the coefficient should be negative. However, the results show a different situation. People move to receive medical treatment that is not necessarily the most complex. Moreover, it is statistically significant that the regional industry with a specific policy aimed at achieving a high level of complexity does not affect this mobility process or, at least, it does not involve large numbers of patients.

[8] Data from the Italian Ministry of the Interior, Historical Archive of Elections: http://elezionistorico.interno.it.

[9] For a more detailed analysis, see the SDO annual report of the Italian Ministry of Health: http://www.salute.gov.it.

Then, let us look at the percentage of public beds over the total number; a piece of data extracted from the SDO annual report of the Italian Ministry of Health. Table 6 suggests that increasing the weight of the public sector within the regional industry, the efficiency and the perceived quality of the treatment will increase. The interpretation of this result could be linked to the profit target. In other words, the private sector could focus on making profit instead of caring for the patients and therefore each minimization process (e.g. hospitalization time) negatively affects the people's perception.[10] Obviously, this minimization process works better where higher economic incentive is given to the private sector.

Finally, in line with our targets, let us analyze the most interesting explanatory variable: Clinical Research. According to the Italian Drug Agency's database (AIFA), all phase II and III studies are considered in this variable. Moreover, to normalize the collected data, the number of regional studies in relation to the national total number is considered and a natural logarithmic transformation has been applied. Taking pharmaceutical clinical research into account, this variable suggests the degree of innovative medical options in each region against the whole country.

The coefficient is both significant and negative. This means that by increasing the pharmaceutical clinical research the patients' perception of the quality of regional industries will increase. The hypothesis of good perception might be linked to the approach of the physician who, as explained in the second section, should be closer to the patient. In doing so, medical research would appear more interested in the clinical case of each research subject. Considering the specific moment of anxiety and fear in which the patient is living, the perception of being important to the physician and of receiving attention is a dominant factor in the judgment of the medical facility. The innovative aspect that this paper suggests and supports with the OR is specific positive externalities, i.e. the positive link between the reputation of medical care industries and pharmaceutical clinical research.

Taking the Malmquist indexes into account, Table 7 shows the relation between pharmaceutical clinical research and the change in efficiency component. This table supports the above mentioned positive relation between pharmaceutical clinical research and efficiency of regional medical care industries. The proposed model is a regression considering the variation of change in efficiency between 2002 and 2006 as a dependent variable, whereas the same variation in clinical research is considered as independent variable. Column B is the same model but applying the bootstrap option with 1000 replacements. Obviously, it has been tested that residuals are independently normally distributed with zero mean and constant variance.

Even if the R-square is relatively low and the *F* statistic is not perfect, considering the Malmquist indexes, the results suggest that pharmaceutical clinical research is able to directly increase the efficiency of regional industries and the patients' perception of good quality. In other words, research is able to ensure a better position in comparison to the other competitors on the national medical care market. With regard to all the previous independent variables; note that pharmaceutical clinical research is the only explanatory variable with a statistically significant relation.

Still considering Table 6, can the analysis be extended further? Table 8 considers the case mix index with respect to the average, taking all the Regions into account.[11] The first column only looks at observations with a complexity higher than the average, whereas

Table 7
Relation between change in efficiency component and clinical research (regression model)

Variables	*A* Change in efficiency	*B* Change in efficiency
Clinical Research	0.131[b]	0.131[b]
	(0.0752)	(0.0614)
Constant	0.764[a]	0.764[a]
	(0.0738)	(0.0608)
F statistic (*p* value > *F*)		
Prob > *F*	0.0965	0.0240
Observations	21	21
R-squared	0.139	0.139

Standard errors in parentheses.
[a] $p < 0.01$.
[b] $p < 0.1$.
[c] $p < 0.05$.

the second column only considers observations with lower values. As for the Case Mix Index higher than 1, three explanatory variables are significant (i.e. Political Change, Case Mix Index and Clinical Research) with the same remarks made about Table 6. The situation is different if the complexity is lower than 1, in which case only the political change variable is significant.

This result is perfectly coherent with the thesis proposed in the second section and Table 3. Where the mobility is negative (emigration > immigration), i.e. in the Islands and the South of Italy, clinical research as well as the complexity of the hospitalization are insignificant since there is no trust in the supplier. The issue is completely different in the North and Center of Italy where patients believe in the system and therefore pharmaceutical innovation has a plus value in the efficiency score.

How can the regional dummy variables be interpreted? From a technical point of view, each coefficient represents what would happen, in terms of efficiency scores, moving from the Region Abruzzo to another region. An interesting explanation of this results could be linked to the management of these industries, that is to say the coefficient could be considered as an evaluation metric of organization and management of resources (i.e. inputs) and then of political choices.

Applying the second step suggested by Simar and Wilson (2007), the approach deals with a truncated regression. Table 9 presents this regression model. Column A represents the truncated regression with the lower limit for left truncation equal to 1, whereas columns B represents the same analysis but applying the bootstrap option with 200 replacements. In both cases all the regression coefficients in the fitted model are zero and therefore the hypothesis is rejected. Moreover, it has been tested that the error terms are independently normally distributed with zero mean and constant variance. As the results in the table show, Political Change and Case Mix Index are not significant. One case is completely different from the findings of the random effects analysis. A possible interpretation might be linked to the fact that the models used are different from a technical point of view. The random effects technique uses a generalized least square methodology to estimate the regression parameters whereas the truncated regression uses the maximum likelihood method. Moreover, the latter model considers all the observations in a single time period as a pooled regression. Evidently, in this case, the timing effect might be determinant.

However, focusing on the main goal of this analysis, even if the model changes, the hypothesis suggested still works: a positive relation between pharmaceutical clinical research and patients' perception. Moreover, both the statistical significance (p-value from 0.010 to 0.000) and its coefficient (from −0.296 to −0.664) increases.

[10] A clear example of this issue is judgment nr. 8254/11 of the fourth penal section of the Italian Supreme Court entitled to quash a judgment. It highlights that the patients' health status has priority over economic processes such as the minimization of hospitalization time in order to maximize the expected profit.

[11] Regions have been considered in the model as dummy variables and, for this reason, the Region Abruzzo has not been introduced in the regression.

Table 8
Relation between efficiency scores and key factors for the case mix index (cross-sectional time-series regression model with random-effects option)

Variables	Efficiency scores	
	Case mix > 1	Case mix < 1
Political change	0.301[a]	0.330[c]
	(0.115)	(0.191)
Clinical research	−0.508[a]	−0.0909[a]
	(0.136)	(0.393)
Case mix index	5.934[a]	5.694
	(2.000)	(3.608)
Public	1.024	−3.123
	(1.739)	(2.407)
Basilicata[e]	0	1.113[b]
	(0)	(0.566)
Calabria[e]	0	2.494[a]
	(0)	(0.656)
Campania[e]	0	1.885[a]
	(0)	(0.596)
Emilia–Romagna[g]	−5.453[b]	0
	(2.182)	(0)
Friuli Venezia Giulia[g]	−5.766[b]	0
	(2.311)	(0)
Lazio[f]	0	−0.273
	(0)	(0.611)
Liguria[h]	−5.755[b]	0
	(2.295)	(0)
Lombardia[h]	−5.115[b]	0
	(2.146)	(0)
Marche[f]	−4.965[b]	0
	(2.138)	(0)
Molise[e]	0	0.217
	(0)	(0.569)
Piemonte[h]	−4.564[b]	0
	(2.268)	(0)
Puglia[e]	0	1.100[a]
	(0)	(0.306)
Sardegna[d]	0	4.728[a]
	(0)	(0.328)
Sicilia[d]	0	3.633[a]
	(0)	(0.442)
Toscana[f]	−5.660[a]	0
	(2.277)	(0)
Autonomous Province of Trento[g]	−5.113[b]	2.101[b]
	(2.274)	(1.040)
Autonomous Province of Bolzano[g]	0	0.392
	(0)	(0.685)
Umbria[f]	−5.821[a]	0
	(2.174)	(0)
Valle d'Aosta[h]	−7.527[a]	0
	(2.443)	(0)
Veneto[g]	−5.445[b]	0
	(2.193)	(0)
Constant	0	−4.674
	(0)	(3.406)
F statistic (*p* value > *F*)		
Prob > *F*	0.0000	0.0000
Observations	51	51
Number of Regions	11	11
R-squared		
Within	0.3806	0.2219
Between	1.0000	1.0000
Overall	0.9232	0.9645

Standard errors in parentheses.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.1$.
[d] Symbols near to Regions indentify ISTAT geographical area: Islands
[e] Symbols near to Regions indentify ISTAT geographical area: South.
[f] Symbols near to Regions indentify ISTAT geographical area: Center
[g] Symbols near to Regions indentify ISTAT geographical area:North-east
[h] Symbols near to Regions indentify ISTAT geographical area:North-west

Table 9
Relation between efficiency scores and key factors (truncated regression model)

Variables	Efficiency scores (A)		Efficiency scores (B)	
	(1)	(2)	(3)	(4)
	Eq. (1)	Sigma	Eq. (1)	Sigma
North-west	−3.674[a]		−3.674[a]	
	(0.665)		(0.608)	
North-east	−3.794[a]		−3.794[a]	
	(0.560)		(0.458)	
Center	−4.171[a]		−4.171[a]	
	(0.587)		(0.440)	
South	−3.287[a]		−3.287[a]	
	(0.338)		(0.301)	
Political Change	0.481		0.481	
	(0.317)		(0.302)	
Clinical Research	−0.664[a]		−0.664[a]	
	(0.158)		(0.189)	
Case Mix Index	3.369		3.369	
	(2.897)		(2.154)	
Public	−9.089[a]		−9.089[a]	
	(1.662)		(1.614)	
Constant	−0.850	0.810[a]	−0.850	0.810[a]
	(2.976)	(0.0928)	(2.312)	(0.0633)
F statistic (*p* value > *F*)				
Prob > *F*	0.0000		0.0000	
Observations	102	102	102	102

Standard errors in parentheses.
[a] $p < 0.01$
[b] $p < 0.05$.
[c] $p < 0.1$.

From the policy maker's point of view, which might be the path towards the efficiency? In other words, how is it possible to shape a public policy aimed at increasing the perceived quality of medical care industries? Considering the results of the OR as well as the main hypothesis of the second section, the conclusion presents a potential direction.

4. Conclusion

Are patients truly able to recognize a bad/good medical care supplier? In Italy, a mobility process does exist: patients move from a region to another in order to receive appropriate medical treatments. This paper suggests that behind their mobility there is a decisional process based on the perception of bad/good supply of health services, a process through which patients can estimate the physicians' effort in making diagnoses and performing medical treatments, thus validating a previous good reputation. The patients' perception might affect how they choose the medical institution. This paper is not able to establish if the mobility is motivated or not, that is to say if the patients' perception is right, but it can support some hypotheses on what could affect their perception. Pharmaceutical clinical research is included in this specific background.

With reference to the areas of health OR, this paper is collocated between the first and the second life cycle stage, that is to say between *identifying consumer requirements* and *developing a new service*. Taking Italy into account, what this paper suggests is the existence of a specific service through which the medical care industry can increase the perceived quality of its treatments and, by doing so, boost its efficiency.

The second section suggests the key factor adopted by the patients to estimate the physicians' effort is the medical approach to their clinical case. At the same time, the section introduces the idea of innovative medical treatment and explains the physicians' strategy in the enrollment process. The third section empirically supports the hypothesis of a positive relation between efficiency scores and pharmaceutical clinical research (a plus value might validate a previous patients' positive impression). Is this opportunity a viable path to increase efficiency? What might happen if the medical institutions try to develop this specific kind of service in order to satisfy the patients' need to gain trust in this process?

On the one hand, pharmaceutical clinical research is an opportunity to increase the scientific knowledge of society as a whole and of each single physician involved in the trial as a medical researcher. On the other hand, since the treatment is free and the research activity is paid for by the pharmaceutical company, it might be an opportunity to increase the financial resources of these medical institutions. Apparently, there are no contraindications in this specific path to achieve efficiency for what concerns quality (perception) or, at least, if we consider the healthy people as well as the young generation since patients can be harmed by this experimental activity. Indeed, according to Calabresi (1969), there is the necessity to achieve "...an adequate balancing of present against future lives and still sufficiently indirect and self-enforcing as to avoid clear and purposive choices to kill individuals for the collective good...". This is the only open issue that a public stakeholder should consider in developing a program aimed at increasing pharmaceutical clinical research, i.e. implementing a protection system able to guarantee the patients' rights and their safety.

The strategy should be very clear: operating on the market of human experimentation to be competitive on the market of medical care, considering clinical research as an innovative service to costumers. In other words, to increase the quality of regional industries, a winning strategy is to have policies aimed at increasing the number of studies through an efficient protection system, minimizing the time required to authorize the trial (i.e. transaction costs), and an appropriate incentive system behind the medical researchers' choice to be involved in an experimental trial.[12]

However, people's socio-economic and socio-demographic conditions are a constraint to further analysis. The analysis assumes that there are no differences in those conditions, i.e. relatives and/or economic means do not affect the mobility process. Also, this work implicitly assumes that a patient's relatives, as well as friends and colleagues, are homogeneously distributed among the Italian regions. These people are the best collectors of information that is used to estimate the outputs' good/bad quality. Even if they are coherent, these assumptions are bounded by data availability and future works should focus on investigating this effect in order to improve knowledge about this phenomenon. It would also be stimulating to study each single medical care supplier, as well as in another European country and how the proposed hypothesis changes according to the considered sample of patients.

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[12] For an in-depth analysis of these policies, the reader can see Ippoliti (2010). The paper suggests that the bargain cost (i.e. the cost to start a trial) could be the key of pharmaceutical companies' choice of the locations involved in an international trial. At the same time, it is highlighted how a social recognition of research activities, as well as a public economic incentive instead of a private one (i.e. pharmaceutical fee), could be practicable path to increase the national research propensity.

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