The effect of system processes and structures on the performance of health care delivery systems: a mixed-method approach

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Abstract  
Mixed methods research is interesting to understand complex processes. Health services are complex processes in search of improving final performance in times of budgetary restrictions. As main objective in this article a mixed method approach is used to quantify the technical efficiency and the excellence reached in health systems and to proof the influence of organizational structures and internal processes in the observed technical efficiency. The results show that it is possible to implement mechanisms for the measurement of the different components by making use of quantitative and qualitative methodologies. The analysis show a positive relationship between the levels related to the Baldrige indicators and the observed technical efficiency in the donation and transplant units of the 11 analyzed hospitals. Therefore it is possible to conclude that high levels in the Baldrige indexes are a necessary condition to reach an increased level of the service offered.

Keywords: mixed methods research, health services, technical efficiency, Baldrige indicators, donation and transplant processes

1. Introduction

Health care delivery systems are in need of fundamental changes if they are to provide increasing levels of service delivery under more demanding circumstances and severe budget constraints. Current structures in health care do not make the best use of their resources resulting in suboptimal care processes and resource overuse (Chassin et al. 1998; Schuster et al. 1998). Health care systems can be characterized as a set of connected or interdependent parts or agents, including caregivers and patients, bound by a common purpose and acting on their knowledge and clinical evidence. They are complex due to the great number of interconnections within and among small care systems. For example, organ transplant and donation services are consisted of a mesh of health care units within hospitals linked to other
In response to the challenge of how to best optimize the resource utilization in health care, there is an increasing interest, according to published literature, on the analysis of productivity and efficiency achieved in health care systems, Hollingsworth (2003, 2008).

With regards to this challenge two are the main purposes of this paper (1) provide formal methods to conduct quantitative appraisal of the performance observed in health care delivery systems and (2) further investigate the effect of systems processes and internal structures on this performance.

We have chosen for the empirical analysis the Organ donation process. It constitutes an interesting case of study in mix method approach as it entails very delicate and complex set of processes involving several, very specialized, experts working in disparate organizations with rather different structures and resources. It demands lots of resources that must be efficiently managed.

In two-stage DEA models statistical inference is performed by regressing resulting DEA scores over some covariates (Hoff, 2007; McDonall, 2009). As emphasized in Simar (2011) and Hollingworth (2008) two-stage DEA modeling requires special considerations regarding the assumed distributions of the variables considered.

By definition most basic forms of DEA assume a separability condition, i.e. that the support of the output variables does not depend on external factors. In some circumstances implying separability might lead to inaccuracies as the frontier might not be invariant to external factors (Simar & Wilson, 2007). For instance in a health care context the amount of population assigned to a hospital or the age of patients being serviced arguably influence the quality, and the quantity, of the theoretical maximum output. Assuming complete separability as is usually the case in DEA analysis may not be optimal under some circumstances.

Parametric approaches, on the other hand, do not require the assumption of separability as the modeling of the dependence of the output variable on external factors is performed either (1) by factoring in these factors into the technology function or (2) by imposing certain restrictions on the statistical moments of the factors and the response variable.

With regards to the existing limitations observed in parametric models, this paper develops an approach to compute technical efficiency providing enough flexibility in the model structure to allow for (1) multi-output analysis of technical efficiency as well as (2) the modeling of complex data structures present in longitudinal observations or hierarchical business units in health care.

With regards to the second purpose of the paper, i.e. understand the impact of internal processes within health care units in the observed performance, a qualitative research study was conducted whereby each service unit was characterized based on the Baldrige criteria.

The rest of the paper is structured as follows, section 2 provides a formal method to conduct quantitative analysis of technical efficiency in a set of organ donation and transplant service units. Section 3 characterizes organizational routines and processes within those service units. Section 4 builds upon previous sections to build causal models explaining the relationship between organizational routines and observed performance and section 5 offers conclusions.

2. Theory development

Health care systems are adaptive because, unlike mechanical systems, they are composed of individuals—patients and clinicians who have the capacity to learn and change as a result of experience. Their actions in delivering health care are not always predictable, and tend to change both their local and larger environments. The
unpredictability of behavior in complex adaptive systems can be seen as contributing to huge variation in the
delivery of health care (Crossing the quality chasm Report, 2000).
This calls for systemic approaches in which health care services follow a Service-Dominant logic, S-D logic (Vargo
& Maglio, 2008; Spohrer, 2008). Organ donation, an instance of this type of healthcare servicing, fits in the
foundational premises for S-D logic as suggested in Vargo & Akaka (2009) in the sense that organ donation is a
service in which some competences, donation capabilities, are applied for the benefit of others. There exists an
indirect service exchange between provider and adopter mediated by hospitals and physicians. Operant resources,
such as surgeons, are key to the service in contrast to operand resources which play a secondary role in determining
effectiveness (López et al., 2011).
Value is always co-created in organ donation processes by several parties engaged in closed collaboration, each of
them offering a specific core competence (Prahalad & Hamel, 1990). There is no single entity fully responsible for
value delivery. Customers, in this case experts at the receiving hospital, play an active role by deciding under which
conditions a donation is to be performed according to medical characteristics. In most cases, they even travel to the
donating hospital to harvest organs by themselves.
Following organ donation service will be described in terms of two basic construct in S-D logic: service systems and
service interactions occurring between them. It is increasingly evident that patient outcomes are not solely a function
of efficacious clinical interventions and practices. Delivery-system research may be viewed as the systematic study
of healthcare organizations, including interchanges with their external environments (e.g., markets, regulators,
competitors) and interactions among internal components (e.g., employees, technology, work processes, culture),
that affect how care is organized and provided (Chassin, 1998).
The goal of delivery-system research is to use research evidence to systematically identify which system processes,
structures, or strategies are most effective for improving outcomes for patients and to use such evidence as the basis
for implementing interventions and formulating policy to shift care to these value-maximizing options across the
healthcare system.
The difficulty in the design of the system processes where many different specialists take part has much to do with
the way the transfer of knowledge is provided (Grant, 1996; Nonaka and Takeuchi, 1995) and in structures where the
tacit component is high (Stamp, 1995; Davenport, 2002; Hopp et al., 2009) even in contexts where there is a clear
description of the structures and results (Becker and Huselid, 1998). Besides, for the structure designs being efficient,
they must be able to get adapted to new scenarios and dynamic (Teece, Pisano and Shuen, 1998). This way they will
be aligned with the evolution of scientific and technological possibilities by keeping optimal standards in response
times.
Besides, the need to maintain and generate dynamic capabilities in system processes joint to the need of managing
tacit knowledge, difficult to turn explicit, makes it necessary the use of coordination mechanisms that exceeds
excellent organizational routines and that warranty the proper climate to promote interdependent and
multidisciplinary processes (López et al., 2011).
Drucker (1991) considers that one of the main elements to incentive the productivity and the performance in
structures is the association of people that work together for similar purposes. Pisano (1994) suggests that although
there are not universal formulas to favor the transfer of knowledge and learning, the existent ones depend each time
more on the organizational structures. A group of authors (Van de Ven et al., 1976; Argote, 1982; Keller, 1994)
suggests that the link between incremental uncertainty and more informal coordination models drives to the
achievement of higher performance in system processes. Gitell’s model is aligned with the mentioned authors since
her research is more focused in the roles that take part in a certain process than in the relationships between individuals.

It is therefore through these structured relationships around the various roles that take part in the clinical process, as decision taking models can be constituted. Apart from this, the application of this model will help increasing the flexibility in the distribution of tasks, responsibilities and organizational circuits according to the uncertainty that characterizes structures in healthcare Institutions.

Taking into consideration the previous statements, the relational coordination model appears as an enabler mechanism to reach better performance of the whole process. Gittell’s model (2010) offers a global coordination action that puts into action the implementation of cooperative practices by facilitating the establishment of pro-active organizational designs with a trend of resource rationalization.

The implementation of the model can reach the performance of elements by producing a “dynamic continuum” of feedback as a quality improvement strategy (Deming, 1986). Health systems must act as business in the way of optimizing the lack of resources. The relational coordination model constitutes an outstanding reference since it has been previously validated in Heath Institutions (Gittell, 2009; 2010).

By taking into account previous research analysis on mutual adjustment (Thompson, 1967; Van de Ven et al., 1976; Tushman and Nadler, 1978; Argote, 1982; Kogut and Zander, 1996) and the coordination focus based in the relations (Weick, 1993; Heckscher,1994; Liang et al., 1995; Faraj y Sproull, 2000; Quinn y Dutton, 2005; Faraj y Xiao, 2006; Heckscher y Adler, 2007; Heckscher et al., 2009) in corporative contexts of high/low uncertainty, Gittell develops the model as an approach to study relational dynamics. In this sense, she defines her model (Gittell, 2002b:3010) as: “A mutual process of reinforcement of the interaction between the communication and the relationships developed to achieve the integration of tasks”. She also specifies than her model differs from others in the way they integrate the three specific dimensions that are required in an effective coordination system. While other recent theories emphasize the importance of shared knowledge, the relational coordination model argues that, being it a necessary condition, it is not enough. According to this, for the reaching of an effective coordination, the agents must be connected through sharing goals and mutual respect (Gittell, 2010). The relational coordination model puts emphasis more in the existent relations that interact in the process more than individual relations amongst different work profiles. According to the model the coordination based in roles has an advantage over the coordination based in personal relations. Although the first one can require of a big investment for its implementation, the second one, the coordination based in roles, promotes the interchange of them and stimulates the corporative flexibility to get adapted to the changing environment in a framework of high uncertainty and interdependencies along time.

The model is structured around two dimensions: communication and relationship

In the communication dimensions we find: frequent communication: it helps establishing relationships amongst roles attending to proximity as a consequence of repeated interaction (Gittell, 2010); timely communication: the delayed communication can have negative consequences for the results in the organization. From this it comes the importance of having the proper communication in the system at the precise moment to reach success in final results (Waller, 1999); accurate communication: a precise communication containing relevant contents plays a critical role in final firm’s results (O’Reilly and Roberts, 1977).

Problem-solving communication: an effective coordination requires that the agents taking part in the task have a compromise to practice a communication oriented to solve the problems that appeared in a group final results characterized by a high interdependence, instead of blaming others or avoid their own responsibilities, which leads to negative consequences that highly affects final performance (Deming, 1986).
Amongst the relational dimensions included in Gittell’s model we find:

**Shared goals:** it takes a key role for the coordination of highly interdependent tasks (Wageman, 1995; Saavedra et al, 1993). By means of a group of shared objectives according to the work process, the agents develop linkages that allow them reaching compatible conclusions with different ways of thinking and acting, as new information is available (Gittell, 2010).

**Shared knowledge:** although Dougherty (1992) describes that the communication amongst the agents taking part in different tasks constitutes a process, it is not always effective, due to different social antecedents having to do with training of accumulated experience, Gittell (2010) manifest that when the agents know how their goals are related with other agents in the same process, a dynamic process where each one knows the impact that each change will have over any task or role in the system.

**Mutual respect:** it establishes a powerful linkage that will be applied in an integral way to the whole process, by generating an effective coordination in the system (Gittell, 2010).

Figure 1 shows the model,

![Figure 1. The relational coordination model (Gittell, 2002)](image)

The model is intensive in communication and relationships, and particularly useful to reach higher degrees of performance in system processes under circumstances showing high levels of interdependence amongst tasks, of uncertainty and time restrictions. This way, it means an example of process improvement that allows a workgroup, department or organization to elevate the frontier of production possibilities to better levels of quality, offering at the same time higher performance (Gittell, 2010).

The model tries to improve work processes by increasing the quality of labor relationships amongst the agents that perform different functions in those processes, reaching this way a higher quality of communication. By reaching relational coordination, the errors, delays and observed structure redundancies that can be observed amongst tasks in the critical processes of a system can be reduced.

So to reach quality in the delivering of healthcare services it is needed:

1. First being able to design and implement processes in the structures
2. To reach levels of relational coordination associated to the system processes

According to the previous literature review, we propose the following hypotheses,

H1. To reach best results, processes must be oriented to the achievement of objectives
H2. More efficient organizations in terms of relational coordination reach best results
H3. High levels of organizational routines and processes positively moderate the resulting technical efficiency

3. Research Methodology

The theoretical approach followed in the previous section adopts a systems perspective, however this raises a number of methodological challenges in the context of delivery-systems interventions as purely quantitative approaches are not sufficient to capture the richness of the context in which the service delivery takes place (Alexander & Hearld, 2012).

The effect that internal system processes and structures exert in observed performance is mediated by a range of human, socio-cultural and organizational factors collectively referred as the context.

Therefore any research in progress needs to take into account the situational opportunities and constrains that affect the occurrence and meaning of organizational activities (Johns, 2006; Griffin, 2007).

As far as research design is concerned this paper adopts a mixed method research in the sense of combining in the research process elements of qualitative and quantitative research in order to achieve breadth and depth of understanding and corroboration (Johnson, 2007).

Evidence in the published literature attests to the current use of mixed methods approaches in health-related research, such as in cardiology (Curry, Nemhard, & Bradley, 2009), pharmacy (Almarsdottir & Traulsen, 2009), family medicine (Stange, Crabtree, & Miller, 2006), pediatric oncology nursing (Wilkins & Woodgate, 2008), mental health services (Creswell & Zhang, 2010; Palinkas, Horwitz, Chamberlain, Hurlburt, & Landsverk, 2011), disabilities (Mertens, 2009), and public health nutrition (Klassen, Smith, Black & Caulfield, 2009).

3.1. Contextualization of organ donation and transplant delivery services

Contextualization is the process whereby knowledge of the settings to be studied is brought to bear in conceptualization, research design, and implementation decisions. In this sense organ donation and transplant services present several important differences compared to other more conventional healthcare service delivery systems. In the first place the distributed nature and strict timing constrains call for high levels of coordination among involved stakeholders (Lopez, 2011).

Contrary to other knowledge-intensive activities, organ donation systems involve a strong component of knowledge tacitness due to the variability of the contexts under which some of the donor-service systems need to perform. Organ transplant is a co-creative undertaking that is specific to each situation depending not only on the donor but at the same time on the recipients’ characteristics (Lopez, 2012). This precludes complete standardization and decision making requires high levels of expertise and the autonomy of experts, in this case surgeons (Hopp, 2009).

A high-level view of this system, depicted in Figure 2, shows three main service sub-systems (1) the hospital hosting the donor (DH), (2) the hospital hosting the recipient (RH) and (3) the agency in charge of coordination nationwide (ONT). Organ donation usually entails about a hundred people working together during short periods of time (maximum 10 hours). These service systems engage in several service systems which, subject to some exogenous factors, must strive to co-create value through successful donor maintenance, fast transportation and successful organ implant. Hence, a large number of agents interact in different ways, organize and adapt to the dynamic conditions under which the service must perform (Matesanz, 2007).
Chapter 3

3.2 Mixed method design

The nature of the hypotheses formulated in section 2 require a dual research approach combining qualitative and quantitative methods of inquiry in order to develop a complete understanding of the influence of system processes and structures in the observed performance in organ donation and transplant services.

The research follows a sequential mixed method design whereby an initial quantitative exploration is followed by several qualitative analyses aimed at explaining in more depth the mechanisms underlying the phenomena under observation (Creswell & Plano Clark, 2011).

Figure 3 provides an overall perspective of the research design adopted in this paper.

Figure 2. Organ donation as a service system (López et al., 2011)
3.2.1 First instrument (Quantitative)

Informally speaking technical efficiency represents the ability of the observed health care unit to maximize the results of the service delivery subject to some resources and constrains, or conversely the ability to maintain the service delivery with lower levels of resource consumption.

Seminal papers on the measurement of technical efficiency, Solow (1957) and Farrel (1957) stated the importance of productive efficiency for policy and economic planning purposes. Twenty years later Charnes et al. (1978) introduced Data Envelopment Analysis (DEA), a methodology able to assess the relative efficiency of multi-input multi-output production units.

At its most basic form DEA computes technical efficiency scores as descriptive measures of the relative technical efficiency of observed decision making units in comparison to a best-practice production frontier. Being of non-parametric nature DEA does not impose any functional form on the production model arguably a key aspect for its widespread application in a variety of contexts from banking (Avkiran, 2009; Seiford & Zhu, 1999; Avkiran, 2011), production planning (Du, Liang & Chen, 2010), R&D performance (Zhong et al., 2011; Yongjun, Yao, Lian & Jianhui, 2012) and agricultural economics (André, Herrero & Riesgo, 2010) among others (Cook & Seiford, 2009).

In some circumstances it might be of interest to ask whether observed firms can improve their importance and if so, by how much. According to Simar & Wilson (2011), such questions can only be answered by inference which in order to be meaningful requires coherent, well-defined statistical models.

The majority of the results presented in the reviewed literature adopting parametric models to conduct efficiency analysis however adopt model structures which are too simplistic, e.g. conventional ordinary least square regression models, to characterize the rich variety present in health care deliveries (Wagstaff, 1989; Hofler, 1994; Zuckerman, Hadley & Lezzi, 1994; Defelice & Bradford, 1997; Chirikos, 1998; Gerdtham, Löthgren, Tambour & Rehnberg,
Moreover conventional parametric models do not allow for multi-output response analysis, arguably an important limitation in the analysis of complex, multidimensional services. With regards to the existing limitations observed in parametric models, this paper follows a parametric multilevel modeling approach to compute the technical efficiency achieved by the service delivery systems under study. For example, hierarchical linear models (HLM) offer a powerful approach to conduct longitudinal analyses across three or more levels (Hofler & Rungeling, 1994). These models are also commonly known by other names, such as mixed-effects regression models and multilevel models (Zuckermann, Hadley & Lezzoni, 1994; Defelice & Bradford, 1997). They are able to recognize the hierarchical structures present in complex service delivery systems.

3.2.2 Second instrument. (Qualitative)

The quality Baldrige criteria (1987) have been applied to stimulate actions for total quality management at firms and analyze the results (Main, 1990, Garvin 1991; Moore, 1995; ASQ, 1998). In year 1998 the criteria were extended in the United States for Health Services (NIST, 2005). The framework for Baldrige criteria for excellence in the performance present a managerial model based in the quality (American Society for Quality, 2005) and the orientation to an effectiveness performance to improve processes (Hutton, 2000; Soussa & Voss, 2002). The model is organized in seven interrelated components: (1) leadership, (2) focus in customers and rest of interest groups, (3) strategic planning (4) the management of human resources (5) the management of the information and data analysis, (6) the management of processes (7) and the management of results for final performance. Many health Institutions are today using Baldrige’s criteria as a tool to self-evaluating the effects of the quality practices in their organizations (Pinzón Martinez, 2003). Figure 4 offers a conceptualization of the Baldrige criteria.

Figure 4. The Baldrige model

4. Results

4.1. Quantitative analysis of technical efficiency in health care
4.1.1. Multi-output, multilevel technology functions

Many kinds of data, including observational data collected in biological and managerial sciences have a hierarchical or clustered structure. For example service delivery units within a given hospital will exhibit more similar characteristics than units from other hospitals. We refer to a hierarchy as consisting of units grouped at different levels. Hence service delivery units may be the level 1 units in an n-level structure where the level 2 units are hospitals in turn aggregated in a level 3 regional health care system.

The existence of such data hierarchies is neither accidental nor ignorable as doing so risks overlooking the importance of the group effects in the analysis and oftentimes renders invalid many of the traditional parametric techniques to the analysis of technical efficiency (Aitkin et al., 1981). An important example of hierarchically structured data occurs when the same individuals or units are measured on more than one occasion. In this case occasions are clustered within individuals that represent level 2 units with measurement occasions level 1 unit.

This paper adopts multilevel generalized linear models as the framework to define technology functions as they (1) provide sufficient flexibility to model clustered structures, (2) allow for non-linear models, e.g. arising in the case of censored variables or count models, (3) allow for the computation of technical efficiency in the case of several response variables. Conventional parametric techniques as presented in section 2.2 are not able to compute the technical efficiency of a combined set of outputs; in this sense this paper provides an interesting extension to the applicability of parametric techniques.

Appendix A presents a panel data corresponding to 11 hospitals involved in the Spanish system for organ donation and transplant for the period [2008-2010]. Every hospital is consisted of a set of service units in charge of: (1) finding adequate donors for potential transplants (2) perform medical processes required and (3) conduct organ transplants (Matesanz, 2007). The panel data represents two outputs: kidney and liver transplants. These transplants are conducted by hospital “id” during the period “year”. Three inputs are considered, the total number of donors, the type of hospital “unittype” and the amount of donors above 70 years of age “donors70_100”.

The following table presents the mean and the standard deviation of the two outputs considered: kidney transplant and liver transplant. According to the data a clear dependence exists among the type of hospital and the moments of the output, this is so as hospitals with advanced technologies (codified with the unittype variable set to 2) are able to conduct more transplants, also advanced hospitals correspond to large cities with larger populations. The data from the table 1 lead us to consider output variables following Poisson distributions albeit with some levels of over dispersion.
Table 1. The output variables

<table>
<thead>
<tr>
<th>Unit type</th>
<th>Summary: Kidney response</th>
<th>Summary: Liver response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Dev.</td>
</tr>
<tr>
<td>Basic transplant services</td>
<td>5.62</td>
<td>4.1</td>
</tr>
<tr>
<td>Neurological services</td>
<td>29</td>
<td>7.2</td>
</tr>
<tr>
<td>Neurological and advanced</td>
<td>23.4</td>
<td>11.1</td>
</tr>
</tbody>
</table>

The large variety in the observed responses, kidney and liver transplants, between hospitals and the levels of overdispersion, i.e. the variance is larger than the mean, render conventional parametric models useless. Moreover we are interested in finding the technical efficiency of each hospital for the combined response of the two outputs: kidney transplant and liver transplant this calls for multilevel technology functions. The following figure 5 represents two different alternatives for technology functions. On the left a two-level model is assumed whereby observations (1st level i) are clustered into service units (2nd level j) where is the random effect capturing the ability of each service unit to perform (e.g. kidney transplants). On the right hand side a three-level model is built upon the previous one, this time each service unit is clustered into hospitals (3rd level k). This three-level model therefore implements a multi-output technology function that allows for the computation of the technical efficiency corresponding to the ability of each hospital to perform as a whole taking into account all service units combined (e.g. kidney and liver transplants). Formally speaking this “ability” corresponds to the technical efficiency as represented by the random effect.
Therefore we entertain a technology function of the form:

\[ y = \beta_1 + \beta_2 x_{2i} + \beta_3 x_{3ik} + \cdots + \zeta_{1k}^{(3)} + \zeta_{2k}^{(2)} x_{2ik} \]

**liver response:** \( y_{ij} \sim \text{Poisson}(\mu_{ij}) \)

**kidney response:** \( y'_{ij} \sim \text{Poisson}(\mu'_{ij}) \)

And imposing a log-link relationship the technology function becomes:

\[
\ln(\mu_{ij} + \delta \cdot \mu'_{ij}) = \beta_1 + \beta_2 x_{2i} + \beta_3 x_{3ik} + \cdots + \zeta_{1k}^{(3)} + \zeta_{2k}^{(2)} x_{2ik} = (\beta_1 + \zeta_{1k}^{(3)}) + (\beta_2 + \zeta_{2k}^{(2)}) x_{2i} + \beta_3 x_{3ik} + \cdots + \\
\]

Previous expression \((XZ)\) corresponds to a multi-output random-coefficient Poisson regression model accommodating: (1) two different responses: liver and kidney transplants, (2) dependence among the repeated observations and (3) dependence among different service units within the same hospital, refer to figure 5.

It is assumed that random effects are of the form \( \zeta_{1k}^{(3)} \sim N(0, \psi_{11}^{(3)}) \) and \( \zeta_{2k}^{(2)} \sim N(0, \psi_{22}^{(2)}) \) with covariance \( \psi_{21}^{(2)} \). Expression (reference to likelihood) is computed via [42].
For the data presented in Annex A, the following table presents the computed estimates for different technology functions: (1) multi-output three-level kidney and liver, (2) single-output two-level kidney and (3) single-output two-level liver.

Table 2. Computed estimates for different technology functions

<table>
<thead>
<tr>
<th>Conditional effects: combined responses</th>
<th>Conditional effects: independent responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC-Poisson: multi-output</td>
<td>RC-Poisson: kidney</td>
</tr>
<tr>
<td><strong>Est</strong></td>
<td><strong>(95% CI)</strong></td>
</tr>
<tr>
<td><strong>Fixed Part: rate ratios</strong></td>
<td></td>
</tr>
<tr>
<td>( \exp(\beta_2) ) [unittype]</td>
<td>1.21*** (1.08,1.36)</td>
</tr>
<tr>
<td>( \exp(\beta_3) ) [donors]</td>
<td>1.10*** (1.08,1.12)</td>
</tr>
<tr>
<td>( \exp(\beta_4) ) [donors70-100]</td>
<td>0.96** (0.94,0.99)</td>
</tr>
<tr>
<td><strong>Random Part</strong></td>
<td></td>
</tr>
<tr>
<td>( \psi_{11}^{(2)} )</td>
<td>0.17</td>
</tr>
<tr>
<td>( \psi_{22}^{(2)} )</td>
<td>0.026</td>
</tr>
<tr>
<td>( \psi_{21}^{(2)} )</td>
<td>-0.066</td>
</tr>
<tr>
<td><strong>Log likelihood</strong></td>
<td>-250.4</td>
</tr>
</tbody>
</table>

For the multi-output technology function, previous table on the left, an increment of the factor unittype represents a 21% increment in the combined response this confirms the large impact that the type of service unit has. An increment in the factor donors represents 10% increment in the combined response. On the other hand increments in the number of donors above 70 years of age, represented by the factor donors70-100, represent a 4% decrease in the combined response of kidney and liver transplants.

The random effect of level 3, representing variations at a hospital level follows a distribution of the form

\[ \xi_{1j}^{(2)} \sim N(0;0.17). \]

The random effect of level 2, corresponding to the effect of the factor unittype in each hospital follows a distribution of the form

\[ \xi_{2ij}^{(2)} \sim N(0;0.0026). \]

4.1.2 Technical efficiency Analysis

In determining the technical efficiency corresponding to the technology function (XZ) this paper assumes an output
orientation as in the considered cased inputs such as the number of hospitals or population are not freely disposable.

For the technology function (XZ) the output-oriented technical efficiency is given by the power of the random effect

\( \eta^{(3)}_{\text{technical}} \)

which represents the contribution to the output that is explained by neither the inputs nor external factors, refer to the following expression.

\[
\mu_{ij} = e^{\eta^{(2)}_{\text{technical}}} \times e^{(\beta_1 + \beta_2 \times x_{1i} + \beta_3 \times x_{2i} + \ldots + \eta^{(3)}_{\text{technical}} \times x_{2i})}
\]

This random effect therefore represents the “efforts” conducted internally by the organization to maximize the outputs conditioned to given inputs and external factors. It is also possible to consider this random effect as a latent variable representing intrinsic characteristics of the hospital which are revealed via the observed outputs, i.e. kidney and liver transplants performed.

The computation of the random effect, and subsequently the technical efficiency, is omitted for clarity purposes, interested readers may refer to [43, Chapter 6]. The table 3 presents the mean and the variance of the two random effects: (1) random-intercept, i.e. technical efficiency and (2) random-coefficient.

Table 3. Technical efficiency corresponding to liver and kidney transplants

<table>
<thead>
<tr>
<th align="left">Hospital</th>
<th>Mean</th>
<th>Variance</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td align="left">Random-intercept</td>
<td>(Technical efficiency)</td>
<td>Random-coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td align="left">1</td>
<td>-.54019696</td>
<td>.25949499</td>
<td>2.1117474</td>
<td>.10144224</td>
</tr>
<tr>
<td align="left">2</td>
<td>-.06833701</td>
<td>.33490417</td>
<td>.02671442</td>
<td>.13092133</td>
</tr>
<tr>
<td align="left">3</td>
<td>.2812933</td>
<td>.34807859</td>
<td>-.10996367</td>
<td>.13607149</td>
</tr>
<tr>
<td align="left">4</td>
<td>-.31050514</td>
<td>.25101169</td>
<td>.12138321</td>
<td>.09812593</td>
</tr>
<tr>
<td align="left">5</td>
<td>.2531918</td>
<td>.21514489</td>
<td>-.09897818</td>
<td>.08410482</td>
</tr>
<tr>
<td align="left">6</td>
<td>.56289722</td>
<td>.16580095</td>
<td>-.22004877</td>
<td>.0648152</td>
</tr>
<tr>
<td align="left">7</td>
<td>.45606749</td>
<td>.18930796</td>
<td>-.1782867</td>
<td>.0740046</td>
</tr>
<tr>
<td align="left">8</td>
<td>-.2067746</td>
<td>.24271143</td>
<td>.08083269</td>
<td>.09488118</td>
</tr>
<tr>
<td align="left">9</td>
<td>-.11436051</td>
<td>.23453519</td>
<td>.04470601</td>
<td>.09168491</td>
</tr>
<tr>
<td align="left">10</td>
<td>-.13384933</td>
<td>.21404345</td>
<td>.05232462</td>
<td>.08367424</td>
</tr>
<tr>
<td align="left">11</td>
<td>-.17941197</td>
<td>.24079713</td>
<td>.07013604</td>
<td>.09413284</td>
</tr>
</tbody>
</table>

The figure 6 provides a graphical representation of the technical efficiency achieved by hospitals considered, each dot representing the mean of the technical efficiency for the considered period [2008-2010] with its associated confidence interval.
Figure 6. The technical efficiency for the considered hospitals

According to the figure we identify 3 different clusters of hospitals according to the technical efficiency achieved: (1) best performers: hospitals \{#6,#7,#3,#5\}, (2) average performers: hospitals \{#2, #9, #10, #11, #8\}, (3) low performer: region \{#1,#4\}.

For the multi-output technology function (expression XZ) the random coefficient in this case is associated with the factor unittype, therefore this random coefficient reflects economies of scale which may arise from an increase in the factor. Based on the mean of the random coefficient in table 2 hospitals #1 and #4 would clearly benefit from an upgrade in their internal service units, e.g. deploying advanced neurological diagnosis.

4.1.3. Organizational routines and observed performance

The previous section provided a ranking of the best hospitals according to their ability to maximize outputs (i.e. kidney and liver transplants) subject to some levels of inputs (e.g. number of donors) and constrains (e.g. age of donors).

In order to investigate on the relationship between organizational routines within service units and the resulting performance this section models each service unit in terms of the Baldrige constructs (i.e. leadership, strategic planning, customer focus, knowledge management, workforce focus and operation focus).

In order to do so a thorough analysis based on the study of protocols implemented in each hospital, existing processes, quality certifications and external auditing has been conducted. Finally these data is triangulated with interviews with service managers in charge of the hospitals under study.

Based on the analysis of previous sources of information and following the Baldrige methodology levels for each construct are defined. Table 4 depicts the levels achieved by each hospital on each baldrige construct along with the total baldrige index (over a theoretical maximum of 550 points).

Table 4. Levels of quality achieved in each hospital according to the Baldrige index
It is remarkable that all of the 11 service units considered manage to achieve excellent levels of quality as measured by the Baldrige index. Hospitals 2, 5, 6, 7 and 9 are at the top mostly due to their prominence in leadership and strategy.

As a preliminary analysis of the relationship between the technical efficiency achieved by each service unit, refer to section 2 and their organizational routines, the following table 5 represents a conventional regression analysis in which technical efficiency is regressed over the Baldrige index.

Table 5. Technical efficiency corresponding to liver and kidney transplants

| Input Variable | Coef. | Std. Err. | T | P>|t| | 95% Conf. Int. |
|----------------|-------|-----------|---|-------|----------------|
| Outcome:        |       |           |   |       |                |
| Technical efficiency |       |           |   |       |                |
| Baldrige Index  | 0.006 | 0.001     | 5.72 | 0.000 | [0.0036, 0.0084] |
| Constant Term   | -2.733| 0.4809    | -5.68 | 0.000 | [-3.821, -1.645] |

R-squared: 0.784 Prob>F: 0.0003

The model explains 78% of the variability of the problem (R-squared 0.78). We see that the variable baldrige positively moderates the technical efficiency achieved and is statistically quite significant. (Coef: 0.006, p-value: 0.000). For illustration purposes a 10% increment in the level of leadership means a 0.072 increment in the technical efficiency achieved according to the model.

The results show that high levels of organizational routines and processes positively moderate the resulting technical efficiency.

4.1.4. Causal relationships between organizational routines and technical efficiency

In order to further investigate the influence of each Baldrige indicator in the observed technical efficiency we conduct a multivariate factor analysis combined with a varimax rotation (references on the methodology):
Table 6. Multivariate factor analysis

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalue</th>
<th>Difference</th>
<th>Proportion</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>5.356</td>
<td>5.116</td>
<td>0.957</td>
<td>0.9571</td>
</tr>
<tr>
<td>Factor 2</td>
<td>0.239</td>
<td>0.193</td>
<td>0.042</td>
<td>1.000</td>
</tr>
<tr>
<td>Factor 3</td>
<td>0.046</td>
<td>0.038</td>
<td>0.008</td>
<td>1.008</td>
</tr>
<tr>
<td>Factor 4</td>
<td>0.007</td>
<td>0.020</td>
<td>0.001</td>
<td>1.009</td>
</tr>
<tr>
<td>Factor 5</td>
<td>-0.012</td>
<td>0.029</td>
<td>-0.002</td>
<td>1.007</td>
</tr>
<tr>
<td>Factor 6</td>
<td>-0.041</td>
<td>.</td>
<td>-0.007</td>
<td>1.000</td>
</tr>
<tr>
<td>LR test: independent v.s. saturated</td>
<td>chis2(15)=111.55</td>
<td>Prob&gt;chi2=0.0000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the previous table 6, we conclude that the dimensionality of the problem may be reduced down to 2 factors according to the proportion of variability explained (i.e. 0.957 and 0.042 for factor 1 and factor 2 respectively). Therefore retaining only 2 factors and performing a varimax rotation gives the factor loadings corresponding to the initial variables (i.e. Baldrige constructs) as represented in table 7 and figure 7.

Table 7. Varimax rotation retaining 2 main factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Uniqueness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leadership (l)</td>
<td>0.764</td>
<td>0.632</td>
<td>0.015</td>
</tr>
<tr>
<td>Strategic planning (s)</td>
<td>0.837</td>
<td>0.544</td>
<td>0.0028</td>
</tr>
<tr>
<td>Customer focus (c)</td>
<td>0.629</td>
<td>0.748</td>
<td>0.0436</td>
</tr>
<tr>
<td>Knowledge manag. (k)</td>
<td>0.599</td>
<td>0.748</td>
<td>0.081</td>
</tr>
<tr>
<td>Workforce focus (w)</td>
<td>0.445</td>
<td>0.896</td>
<td>-0.0014</td>
</tr>
<tr>
<td>Operations focus (o)</td>
<td>0.763</td>
<td>0.393</td>
<td>0.2621</td>
</tr>
</tbody>
</table>
According to the figure we observe that factor 1 measures the level intensity of indicators: “leadership, strategy and operations focus”. Whereas factor 2 measures the level intensity of indicators: “customer focus, workers focus and knowledge management”.

Combining the data (table technical efficiency) with the data (varimax rotation) gives the following results (table 8).
Table 8. Technical efficiency (varimax rotation)

<table>
<thead>
<tr>
<th>Technical efficiency</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.540197</td>
<td>-1.365368</td>
<td>-1.133234</td>
</tr>
<tr>
<td>-0.3105052</td>
<td>-2.428829</td>
<td>0.368478</td>
</tr>
<tr>
<td>-0.2067746</td>
<td>0.5289063</td>
<td>-0.5087735</td>
</tr>
<tr>
<td>-0.179412</td>
<td>0.2368888</td>
<td>-2.163429</td>
</tr>
<tr>
<td>-0.1338493</td>
<td>0.5532684</td>
<td>-0.884609</td>
</tr>
<tr>
<td>-0.01143605</td>
<td>0.0794354</td>
<td>0.8061788</td>
</tr>
<tr>
<td>-0.068337</td>
<td>0.0794354</td>
<td>0.8061788</td>
</tr>
<tr>
<td>0.2531918</td>
<td>0.3989328</td>
<td>0.583496</td>
</tr>
<tr>
<td>0.2812933</td>
<td>0.239393</td>
<td>0.7124175</td>
</tr>
<tr>
<td>0.4560675</td>
<td>0.55121</td>
<td>0.7432994</td>
</tr>
</tbody>
</table>
| 0.5628972            | 1.126726       | 0.3016275      |}

Factor 1
Factor 1 measures leadership, strategy and operations.

Factor 2 measures the focus in the medical staff, the customer/collaborators and knowledge management.

The results show that,
1. To reach excellence, the hospitals must show excellence in both dimensions.
2. The units showing high levels in the second dimension could easily improve by putting their efforts in dimension 1.
3. In a similar way, there are units showing high levels in the dimension 1 that are penalized by a low level in factor 2.
4. Showing low levels in both dimensions implies reaching very low levels in the technical efficiency.

5. Conclusions and future areas of research

Two have been the main purposes of this paper (1) provide formal methods to conduct quantitative analysis of
technical efficiency in health care and (2) further investigate the impact of internal processes within health care units in the observed performance.

Health delivery systems present two important characteristics: interdependence and capacity of adaptation. Both characteristics make complex the management and evaluation of these systems. The present work has taken as an example of complex healthcare system the donation and transplant system in a region of Spain.

This paper adopts a mixed method research since it combines in the research process elements of qualitative and quantitative research in order to achieve breadth and depth of understanding and validation. By considering the barriers observed in parametric models, this paper follows a parametric multilevel modeling approach to calculate the technical efficiency reached in donation and transplant healthcare service delivery system.

An initial quantitative exploration based in the technical efficiency concept is followed by several qualitative analyses aimed at explaining in more depth the mechanisms underlying the phenomena under observation. For this second part, concepts coming from the relational coordination framework and the Baldrige quality model have been applied. From the literature reviewed and the results obtained in the present work it is possible to argument that the excellence in the offering of services in donation and transplant requires of (1) excellence in the management of operational processes and (2) the putting into action of relational coordination mechanisms amongst the implied systems.

In relation to both components, the operational and relational one, for reaching excellence in healthcare delivery systems, it is possible to implement in the practice mechanisms for the measurement of both components by making use of mixed methods, including both quantitative and qualitative tools. This way, the operational component is estimated by making use of the technical efficiency and the relational one by making use of the Baldrige indexes.

An important conclusion from this work is the existent relation proofed between the levels related to the Baldrige indexes and the technical efficiency observed in the donor and transplant units in the 11 analyzed hospitals in this study. This way it is possible to conclude how high levels in the Baldrige indicators become a necessary condition to get a high level in the service delivering.

As future areas of research we could consider to widen the simple to other health regions to analyze dependencies to a regional level and identify quantitative relationships amongst Baldrige indicators and the observed technical efficiency in other kind of transplants. Having more data could enable the development of detailed analysis about the importance of each Baldrige construct.

References


López D, de Pablos C., De la Puerta, E. (2011). Productivity in service systems: Towards a managerial framework,
Informal Service Science.


