

**THE PURCHASE OF TECHNOLOGY IN HEALTH ORGANISATIONS:
AN ANALYSIS OF ITS IMPACT ON PERFORMANCE**

Alessandro Ancarani, Carmela Di Mauro and
M. Daniela Giammanco*

ABSTRACT. The paper presents an investigation carried out in an Italian health organisation, aimed at studying the purchasing process of medical equipment at the hospital ward level, and at assessing its impact on hospital ward performance. A model of the decision process that leads to purchase is developed. The results show that the acquisition of technology has a positive impact on the ward's relative efficiency, and that efficiency is further linked to the specific goals pursued by the head of ward and by the constraints faced.

INTRODUCTION

The tightening of budget constraints and the introduction of managed competition schemes in the health sector bring to attention the role that investment in technology plays in determining performance and quality improvement. There is, however, limited evidence on how the purchase of medical technology by hospitals is related to indicators concerning activity levels, finance, and quality.

** Alessandro Ancarani, Ph.D., is an Associate Professor, Department of Civil and Environmental Engineering, University of Catania (Italy). His research interest is in public procurement, public service evaluation, and outsourcing strategies. Carmela Di Mauro, Ph.D., is an Associate Professor, Dipartimento di Analisi dei Processi Politici, Sociali ed Istituzionali, University of Catania. Her research interest is in health economics, health care evaluation, and experimental economics. Maria Daniela Giammanco, M.A., is an Assistant Professor, Dipartimento di Analisi dei Processi Politici, Sociali ed Istituzionali, University of Catania. Her research interest is in health economics and health care evaluation.*

Likewise, little attention has been paid to the decision mechanisms governing the acquisition of technology. In many countries, the health sector is strongly characterised by the presence of public organisations, and this implies that the profit maximisation assumption must be replaced with alternative objectives. There are two major actors influencing the acquisition of technology. The hospital management, whose principal goals are efficiency and quality, and the physicians, with their own goals and constraints, who are the internal customers. The consequences of this dual decision process, which makes the health sector rather unique, may be over-investment and excess capacity (Newhouse, 1970). The effects of slack investment are ambiguous: on the one hand, it may lead to inefficiency (Lee, 1971). On the other, slack may also propel innovation and may increase health enhancing quality (Picone et al., 2003).

While there are several empirical contributions which have analysed hospital capital investment at the macro level (Rodriguez-Alvarez & Knox Lovell, 2004), to our knowledge less attention has been paid to how the purchase of technology takes place within hospitals. The present paper investigates in such a direction, with reference to the Italian health sector. The paper presents an investigation carried out in a large Italian Public Health Organisation, aimed at studying the purchasing process at the hospital ward level, and at assessing its impact on hospital ward performance.

Our research hypotheses are that the acquisition of technology has an impact on the ward's relative efficiency, i.e. it is related to efficiency measures, and that efficiency is further linked to the specific goals pursued by the head of ward and by the constraints faced. In order to test these hypotheses, we proceed in three steps. First, a model of the decision process that leads to the purchase of medical equipment is developed; next, a production frontier technique, namely data envelopment analysis (Charnes, Cooper & Rhodes, 1978), is applied to estimate the relative efficiency of the wards under analysis. Finally, a cluster analysis is adopted to investigate whether the ward's goals and constraints are related to efficiency.

Our model of technology acquisition is grounded in the economic literature on non-profit hospital behaviour, with a special emphasis on how the hospital actors' goals and constraints are related to the

decision to purchase equipment and new technology. This leads to the following organization of the article: after a thorough discussion of the relevant literature and sketches the peculiarities of the supply chain in the health sector; the main characteristics of the Italian national health service will be summarised; a reference model will be presented; the study undertaken will be described and the data analysed; the results of the study will be reported. Finally, the article ends with conclusions and a discussion of the implication of the investigation undertaken.

PURCHASE OF TECHNOLOGY IN THE HEALTH SECTOR

Models of Hospital Behaviour

The theory of hospital management has investigated the hospital as characterized by sometimes conflicting interests. A series of theoretical models have explored the way in which the decision making process of the different actors, in terms of goals and constraints, moulds hospital organization and input acquisition and usage. Newhouse (1970) assumes that not-for-profit hospitals seek to maximize the facility's quantity of services and prestige (which in turn is a function of quality), subject to the deficit which the structure can incur. The hospital objective function reflects the interests of different agents: the trustees, the administrator and the medical personnel, who may assign different weights to quantity and quality. Quantity is valued because it is related to the possibility of obtaining gifts and tax privileges. Quality is important for the trustees, the administrator and the medical personnel because they depend on it for their prestige and their professional standing. An increase in quality cannot be achieved without an increase in cost. The size of the allowed deficit weakens the incentive for administrative control of costs. Inefficiency arises because the search for prestige leads to duplication of sophisticated equipment and personnel.

Lee (1971) extends Newhouse's model by introducing competition among hospitals. He envisages managers as the most important actors determining hospital behaviour, and argues that the hospital utility maximization is principally driven by the maximization of hospital status. Inputs are status symbols: the more diverse, numerous and complex the inputs, the higher the hospital status. The interest of the hospital management in input availability is reinforced by the major importance of the physicians to the hospital. Hospital

competition for physicians boosts the expansion and improvement of inventory inputs. The principal result of this model is the generation of slacks. Since input availability defines the status group the hospital belongs to, the inputs that each hospital desires to acquire change as medical technology develops. From this, it follows that each hospital wants to adjust to changes in the pattern of input utilization of its reference status group, which varies with technology. The demand for production factors is kinked. Hospitals will uniquely follow their competitors when the latter increase their input use, but not in case of input reduction.

Harris (1977) acknowledges the dual structure of the hospital. According to Harris, the hospital is split in two separate firms: physicians (the demand division) and administration (the supply division). Physicians demand nursing and technical services which must be supplied by the administration. Demand and supply are disjoint, because each division has its own objectives and constraints. This duality produces a highly sophisticated system of non-price allocative rules. Hospital behaviour evolves as the bargaining process between physicians, acting in the interest of patients, and the management, searching for revenue and prestige. Most often, the necessity to soothe conflicts over the control of hospital capacity leads to expand hospital size and complexity. Therefore, Harris suggests that as soon as external constraints are loosened up, by means of larger insurance coverage or larger availability of funding, slack increases.

The focus on the interaction among the different hospital actors is also present in Zweifel and Breyer (1997). In this model, which largely draws from Newhouse (1970), the hospital tries to maximize its utility function subject to a profit constraint. Under the assumption of free utilization of hospital profit, profit is pursued because it allows to pay premiums to employees and to invest in quality enhancing technology. In this model, the extent of slacks depends on the hospital payment system. Payment systems of hospital services based on cost recovery are not apt to create incentives for efficiency and to reduce slacks. On the contrary, payment systems based on performance may allow for efficiency incentives.

All the above mentioned models predict the possibility of excess capacity, over-investment and over-staffing. It must be stressed, however, that slack is difficult to distinguish from quality (Sloan,

2000). Hence, some of the excess of productive capacity is not to be considered as a waste of resources. Since health services must be personalized and offered only when the demand for them is actually expressed, production cannot be fully programmed (Harris, 1977).

The issue of high input intensity, interpreted as health improving, has been tackled empirically by Picone et al. (2003). These authors find that higher intensity of hospital care engenders both higher survival rates and superior functional status among the survivors. The relevance of slacks for the innovative process has been empirically studied by Nohria and Gulati (1996), who suggest the existence of an inverse U-shaped relationship between slacks and innovation within an organization. Both too little and too much slack harm the innovation process. The authors offer evidence that there is an intermediate level of optimal slack enhancing innovation, and suggest the possibility of the coexistence between two opposite outstanding views. That of Cyert and March (1963) who consider slack as an instrument of latent conflict resolution within the organization, and that of Leibenstein (1969) and Williamson (1963, 1964) who think of slack as a synonymous of waste, the outcome of managerial self-interest, ineptness and indolence, rather than a buffer against unexpected events. Both perspectives may be used to interpret the results of the above mentioned theoretical hospital models.

A Supply Chain Perspective

Chopra and Meindl (2004) define supply chain management as the sum total of parties involved, directly or indirectly, in fulfilling a customer request. This is a very broad customer-centric definition that considers new product identification and development, marketing, operations, distribution, finance, and customer service as part of supply chain management. Although the supply function in hospitals has traditionally been seen as having a limited scope under the term "materials management," innovative hospitals have adopted the idea of a supply chain, which presents a more robust or expansive view of the world of materials.

Applied to hospitals and health organisations, such a definition can be interpreted to include the flow of products and associated services to meet the needs of the actors involved. In fact, the health care supply chain is in many ways more complex and works on many

different dimensions than the supply chain in other sectors. Physicians, nurses, and patients are all part of the supply chain function. Physicians can be viewed as internal customers and participants in the selection, supply management, and use of products. Effective coordination with internal customers allows health care supply chain managers to provide a controlled range and mix of products to meet patients' demand. Therefore, the supply chain management results from a combination of final customer relationship management (CRM) and internal customer preference management (CPM). The most observable, measurable, and valuable outcome of such a management is product standardisation and the associated cost savings. However, a host of other outcomes may be associated with effective CRM and CPM efforts, including improved clinical outcomes, employee and patient safety, better care processes, and strengthened alignment between the objectives of physicians and hospital administrators (Schneller & Smeltzer, 2006).

Physicians have long-standing relationships with suppliers and preferences for certain products. They have been frequently trained in organizations that have favoured one supplier over another and have participated in supplier-supported product development. They also become dependent on suppliers for continuing training and for obtaining technical support in the use of new products. Therefore, physicians frequently have very strong preferences for brand products and are reluctant to accept alternative products, even in the face of evidence regarding equivalence. This is especially true for very expensive medical equipment. All this creates a complex environment for the supply chain manager, who has to weigh the preferences of the physicians against the organisation's quest for efficiency, quality improvement, and innovation.

The internal customer preference for controlling the type and amount of equipment purchased contrasts with the goal of cost containment through standardisation which centralised procurement procedures aim to achieve. Moreover, centralised acquisition procedures may induce physicians to act strategically, in the sense that, since purchases may take place in bundles, and when funding is available, physicians may be tempted to build up slack for future needs. However, as it has been stressed in section 2, slack equipment has no obvious effect on hospital efficiency or quality of care, since slack may be either "waste", i.e. unproductive investment,

or rather may be necessary to face unexpected demand, or represent the basis for technological innovation inside the hospital.

THE ITALIAN NATIONAL HEALTH SERVICE

The Italian National Health Service (*Sistema Sanitario Nazionale*, or SSN) was created in 1978 and underwent a deep structural reform in the nineties. The main features of the current SSN can be summarised as follows: (i) the presence of managed competition on the supply side of health care, (ii) high decentralisation of decisions concerning the provision of health care, (iii) uniform national health levels, (iv) the transformation of health care authorities into health care enterprises or hospital enterprises run according to managerial criteria, (v) a prospective payment system for the reimbursement of hospital services.

In particular, the form of managed competition that Italy has adopted is akin to the so-called “mixed markets” (Cabiedes & Guillen, 2001), with public and private providers competing on the supply side, and purchasing choices made essentially by public agents. A safeguard for consumers meant to avoid adverse selection problems is supplier accreditation (France, 1995).

Health Care Enterprises (AUSL) and Hospital Enterprises (AOs) are run by a General Manager, directly appointed by the regional government on a private contractual basis. Further, a divisional structure has been adopted, and heads of divisions (i.e., wards and ancillary services), called Operating Units (units) annually bargain with the central management the goals to be achieved.

Concerning the effects the reform may have brought on the acquisition of capital inputs by hospitals, the expected impact is ambiguous. The opinion that prevailed in the early literature (see section 2) was that competition among providers and among hospitals in particular resulted in the so-called “medical arms race”, i.e. in rising costs, duplication of services, and under-utilization of equipment. This because, especially in public health service, consumers have free access to health care, or simply contribute a co-payment, so that they are insensitive to the cost of production of services. If the higher medical care intensity leads to benefits in health outcomes which are valued less than the cost of achieving

them, then competition is socially wasteful (Kessler & McClennan, 2000).

The rise and diffusion of managed care practises worldwide, with its beneficial effects on costs, has partly changed this view (Magnussen & Rivers Mobley, 1999). With specific reference to the Italian case, the tighter budget constraint, the cost centre accounting method, and the negotiation of goals between the enterprise central management and its wards/ambulatories should lead to purchases that are meant to improve the quality and/or the efficiency of health care provision, and should discourage the accumulation of excess capacity. Especially where the prospective payment system applies (i.e. hospital enterprises), health suppliers may be reluctant to purchase equipment which does not increase demand or does not cause a switch toward more complex case-mixes, because this would reduce the return on the investment (Chalkley & Malcomson, 2000).

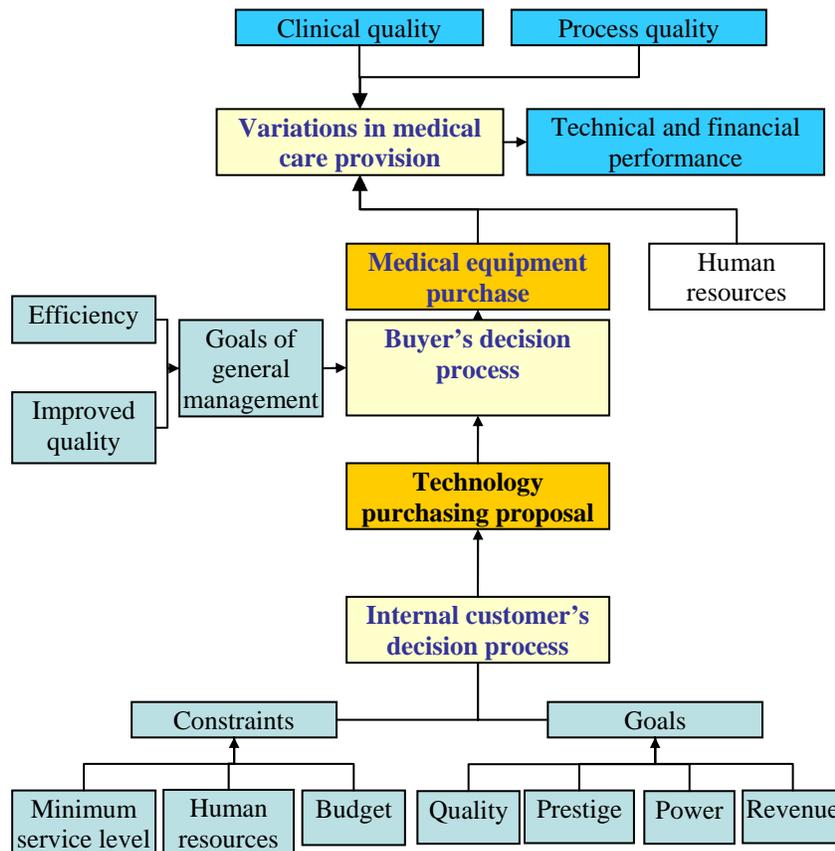
On the other hand, the very fact that every supplier is a price-taker in a competitive environment implies that she should follow suit competitors' investments which may divert or change the composition of demand in unsolicited fashion. This effect is further strengthened since in the Italian case, competition is not acted on the basis of price, but rather on the basis of hospital status (Lee, 1971), or hospital location (Kessler & McClennan, 2000). Assuming quality of care is a multi-attribute concept (Chalkey & Malcomsom, 2000), medical equipment may be one of the attributes most easily observable by patients. Thus, the hospital management may encourage the purchase of new and sophisticated equipment in order to increase its market share. As a result, it is not unlikely that, similarly to what happens under the monopolistic competition market structure, excess capacity is observed in equilibrium (Joskow, 1980).

A REFERENCE MODEL

In previous sections the literature on hospital behaviour has been outlined, and attention has been given to the possible ways in which the design of the National Health Service may provide incentives towards the efficient purchase of equipment by hospitals. Further, the characteristics of the hospital supply chain have been underlined, arguing that the internal customers', i.e. physicians', preferences must be accounted for by supply chain managers.

This section sketches a model (Figure 1) of the purchase of equipment in an Italian public hospital. The model brings together the goals and constraints of the main decision makers inside the hospital, namely physicians and administrators, the decision process that leads to the purchase of medical equipment, and the final effects in terms of changes in quality of care and efficiency of production.

FIGURE 1
Methodological Framework for Evaluating the Impact of Medical Equipment Purchase



As described above, the acquisition of technology is a decision process which involves several actors. The proponent is usually the head of a ward/service (internal customer), who is a physician. The General Manager of the hospital (buyer) has the final word in the decision on whether to buy or not.

Since the Italian health sector is strongly characterised by the presence of public organisations, the profit maximisation assumption must be replaced with alternative goals. The hospital management's objectives are generally those of efficiency and quality improvement. The physicians' utility is increasing in prestige (which is a function of quality) and personal power inside the hospital. In addition, since in the new SSN the heads of ward are rewarded also on the basis of their contribution to the hospital financial performance, the net revenue generated is another argument of the internal customer's utility function. The internal customer maximises his personal utility, subject to a series of constraints, fixed by the buyer.

It is assumed that the management's decision variables are labour and capital inputs. As far as the physicians' decision process is concerned, discretion can be exercised mostly in the proposal for the acquisition of medical equipment, and personnel can be considered a quasi-fixed input (Rodriguez-Alvarez & Knox Lovell, 2004).

The internal customers have their own utility in obtaining certain technological inputs, because they derive benefits in terms of personal prestige and power both inside and outside the hospital, improved working conditions, and better and new health services. Given the internal customer's utility function described above, the acquisition of new equipment may conflict with the goal of efficiency. Such a behaviour is further made possible by the presence of asymmetric information concerning the effective expected benefits of the technology acquisition. Thus, the buyer cannot have full control over expenses for medical technology.

Summing up, the model makes the hypotheses that the acquisition of technology is driven by the specific goals pursued by the head of ward and by the constraints faced, and that, in turn, technology acquisition has an impact on the ward's relative efficiency. Hence, goals will finally be related to efficiency. The following sections present a test of these hypotheses, based on a case study. In particular, the motivations underlying the purchase of ecographers by nineteen units of a large Italian AUSL are identified and their relation

with the units' technical efficiency is explored. The choice of focusing on the acquisition process of ecographers, has a rationale. It follows the criteria of sample dimension, frequency of the purchase, and size of the expenditure. Ecography equipment is used in almost every medical field and often the total expenditure devoted to its purchase is larger than that related to other medical equipment.

In the application, the relative efficiency of the wards under analysis is measured through a production frontier technique (data envelopment analysis). Next, a cluster analysis is adopted to investigate whether the ward's goals and constraints are related to efficiency.

CASE STUDY

The Purchase Process

The Local Health Care Authority 3 (AUSL 3), supplies comprehensive health care to the whole population residing in the province of Catania (Italy). It encompasses an area of almost 3,600 km², embraces 58 local councils and counts a population of 1,115,000 inhabitants. AUSL 3's territorial area is divided in 11 Health Districts, and includes six hospitals.

In order to regulate the purchase of equipment, the AUSL General Manager with the aid of Purchasing Office, has established a set of internal rules and has created the Purchase Planning Group (PPG), made up by professionals belonging to the technical, clinical and financial areas. The set of internal rules governing the purchase process distinguishes three fundamental steps. In the first step, the Head of unit which demands the purchase of new equipment, expresses his/her request by using two standard forms. The first form collects information on the technical characteristics of the commodity to be purchased, the supporting equipment and materials needed for its use, and the estimated amount of money its acquisition requires. The second form collects information concerning the motivations for the purchase, the expected benefits such as shorter waiting lists, a larger number of cases treated, an increase in the quality of the services provided, and its costs and prospective revenues. The purchase request is then judged by the PPG. The PPG performs an economic evaluation of the investment, analyzes and quantifies the costs of acquisition and maintenance, and its prospective revenues.

If the purchase request obtains the PPG appraisal, it is transmitted as a proposal to General Management, for acceptance or refusal. In case of acceptance, the proposal is added to the AUSL Programming Plan, otherwise its denial is transmitted to the Head of unit.

The Questionnaire

The study of the decision process driving to the purchase of medical technology has been carried out by analyzing nineteen acquisitions of ecographers between 2003 and 2006. Ten ecographers were purchased by hospital wards, while the remaining nine by ancillary services. The data were directly collected by means of face-to-face interviews to the Heads of unit, in the period February-March 2007. The questionnaire was made up of six sections of semi-open-ended questions relating to the 2003-2006 period.

The first section of the interview consisted of general questions concerning the unit (such as number of beds, size of staff, variation in the staff size, etc.). This section was also used to obtain information on the ICT endowment of the unit (e.g. number of personal computers; computerised management of patients; internet facilities).

The second and third sections contained questions relating to the characteristics of the commodity purchased (e.g. incremental or substitutive purchase; availability of the same type of medical equipment, etc.), and also tried to collect information concerning the labour/capital ratio of the unit and the know-how of the medical and non-medical personnel relative to the new equipment.

In section 4, respondents were asked to assess the perceived importance of five possible motivations of the purchase:

- i) increasing the amount of tests performed;
- ii) increasing the quality of the service provided;
- iii) reducing the waiting-list time;
- iv) augmenting the prestige of the unit; and
- v) cutting the costs of the unit.

In section 5, heads of unit had to evaluate the level of actual achievement of the above mentioned goals, following the acquisition of the new equipment. They were also asked to assess which constraints could have jeopardized the full utilization of the new equipment:

- i) delays in its delivery;
- ii) unsatisfactory maintenance;
- iii) support equipment;
- iv) insufficient personnel training; and
- v) bureaucracy.

In section 6 respondents had to appraise the importance attached to a series of managerial goals:

- i) maximising the unit's returns;
- ii) maximising the unit's prestige;
- iii) maximising activity levels; and
- iv) maximizing patient satisfaction.

In the same section they also evaluated the stringency of some potential constraints in the management of the UO:

- i) type of patients;
- ii) human resources;
- iii) capital inputs; and
- iv) administrative services.

The questions of sections 4-6 were constructed so as to assign a score from 1 to 5 on a Likert scale, according to the perceived importance of the evaluated items.

RESULTS

Efficiency Analysis

The technical efficiency of units has been measured through Data Envelopment Analysis (DEA), a mathematical programming technique developed by Charnes, Cooper, and Rhodes (1978), aimed at measuring the relative efficiency of a set of decision making units in the presence of multiple inputs and multiple outputs. The input and output data of the units under analysis show what is achieved with the technology available. However, these decision units may exhibit different degrees of efficiency in transforming inputs into outputs and that is what DEA assesses. Its aim is to identify which units operate efficiently and therefore belong to the efficient frontier, and which of them do not operate efficiently, and therefore should make appropriate adjustments in their outputs or inputs in order to increase efficiency.

DEA models can be either input or output-oriented. In the former case, technical inefficiency is defined as the proportional reduction in input usage achievable when output is set constant. In the latter case, technical inefficiency is defined as a proportional increase in output achievable with given input levels. In the present paper an output-oriented model has been considered appropriate because the output-oriented approach allows for the fact that wards are assigned a fixed quantity of inputs, and, therefore, efficiency must be pursued by maximising output.

DEA models can assume either constant returns-to-scale (Charnes, Cooper & Rhodes, 1978), or variable returns-to-scale (Banker, Charnes & Cooper, 1984). The former is appropriate only when the units analysed operate at an optimal scale. However, if the units do not operate at optimal scale, efficiency measures under the constant returns-to-scale (CRS) hypothesis are actually the result of both scale efficiency and pure technical efficiency. The variable returns-to-scale (VRS) model captures pure technical efficiency devoid of scale efficiency effects (Coelli, Rao & Battese, 1998), as it is appropriate in this analysis.

The literature has stressed the need to carry out efficiency analyses within peer groups made up of comparable units, in order to control for potential heterogeneity (among others Chilingirian, 1995; Hofmarcher, Paterson & Riedel, 2002). The main source of heterogeneity among the units of this analysis is the one between units producing inpatient care (wards) versus those producing only outpatient care (services). As a consequence, DEA analysis has been performed separately on the two sub-sets: sub-set A, made up of 10 units which produce both inpatient care and outpatient care, and sub-set B, composed of 9 units which only produce outpatient care.

As for the choice of output and input measures, given the above considerations, for the units producing both outpatient and inpatient care two output measures were used:

- number of ecography tests made by the unit per year; and
- total revenues of the unit.

Two input measures (Cellini, Pignataro & Rizzo, 2000; Hofmarcher, Paterson & Riedel, 2002) were used:

- number of beds; and

- number of employees (medical and non medical).

For the units producing outpatient care, output measures applied were the same as above, while the input chosen was the number of employees.

Results obtained for units producing inpatient care show that most units are on the frontier throughout the period analysed (80% of the unit in 2003, 50% in 2004, 60% in 2005 and 2006). Also, the efficiency scores do not change significantly and are not widely scattered, since the worst score is 1.55. Thus, the general behaviour seems to be relatively uniform.

Results obtained for units producing outpatient care only show that these units exhibit a higher variation through the period analysed. No apparent trend in efficiency emerges except for one unit whose efficiency worsens after 2004 when the ecograpser was bought.

Since changes in the frontier from one year to the other may render comparisons among the DEA scores meaningless, the output oriented Malmquist Index has been computed to evaluate how the units' efficiency changes across the 2003-2006 period.

Following the seminal work by Caves, Christensen, and Diewert (1982), the Malmquist Index is based on the standard distance function. Building on this, Färe, Grosskopf, and Knox Lovell (1985) defined such a productivity measure between the periods t and $t+1$ as the geometric mean of the original index by Caves, Christensen, and Diewert (1982). The Malmquist Index is built as the product of two components. The coefficient $E_o^{t,t+1}$ (efficiency variation) evaluates the different position of the i -th unit with reference to the frontier between periods t and $t+1$, while the coefficient $T_o^{t,t+1}$ (technology variation) evaluates shifts of the frontier due to technology changes between periods t and $t+1$. An index greater/smaller than 1 means an increase/decrease in productivity.

Due to calculation complexity, the Malmquist Index is actually calculated considering the DEA model with constant return-to-scale (CRS). Thus, the scale effects cannot be investigated.

Table 1 reports the Malmquist Indices calculated for the units producing inpatient and outpatient care. In the period 2003-2004, 5 units show an increased productivity, with most of them showing also

TABLE 1
Malmquist Index for OUs with Inpatient and Outpatient Care

OU Denomination	Date of purchase	M ^{03,04}	E ^{03,04}	TC ^{03,04}	M ^{04,05}	E ^{04,05}	TC ^{04,05}	M ^{05,06}	E ^{05,06}	TC ^{05,06}
P1-a	Aug 2004	1.44	1.79	0.80	1.44	1.01	1.42	0.57	0.52	1.09
P1-b	Aug 2005	0.94	0.91	1.03	1.11	1.13	0.98	0.85	0.92	0.93
P2-a	Aug 2006	0.7	1.00	0.7	1.37	1.00	1.37	1.17	1.00	1.17
P3-a	Aug 2007	0.71	0.95	0.75	1.29	0.92	1.40	1.22	1.17	1.04
P3-b	Dec 2003	0.64	1.00	0.64	1.42	1.00	1.42	1.50	1.00	1.50
P4-a	Dec 2003	1.31	1.06	1.23	0.98	1.00	0.98	0.77	1.00	0.77
P2-b	Aug 2007	1.12	1.00	1.12	0.94	1.00	0.95	0.86	1.00	0.86
P5-a	Dec 2003	1.16	1.27	0.92	0.95	0.83	1.14	0.79	0.78	1.01
P5-b	Oct 2005	0.88	0.98	0.90	1.21	1.02	1.19	0.97	0.97	1.00
P3-c	Jun 2006	1.22	1.15	1.07	0.77	0.80	0.96	1.08	1.20	0.90
D1	Dec 2003	1.52	1.48	1.03	1.44	1.26	0.75	1.04	1.26	1.17
D2-a	Dec 2003	1.01	1.00	1.01	1.11	1	0.77	1.16	1.00	1.16
D3	Aug 2004	0.82	0.83	0.99	1.37	1.29	0.80	0.76	1.29	1.15
P4-b	Jun 2006	0.54	0.55	0.99	1.29	1.89	0.80	1.51	1.89	1.15

increased relative efficiency and increased technological level. It shows that 2 units out of 3 which bought the ecographers in December 2003 increased their efficiency in the following year. Also for the units which purchased the equipment in August 2004 an increase in the efficiency is observed in the following year, except for 1 unit (P2-b) which displays a small decrement in efficiency due to a shift in the frontier. The unit which purchased in 2005 practically no variation emerges in the following year. Therefore, this analysis suggests that for most units a positive variation in efficiency occurs the year after the acquisition. The Index also points out that as the availability of the new equipment becomes common to all units, the effect on relative efficiency disappears.

Table 2 reports the Malmquist Indices calculated for the units producing only outpatient care, with substantially similar results to those referring to Table 1.

TABLE 2
Malmquist Index for DMUs with Outpatient Care

OU Denomination	Date of purchase	M ^{03,04}	E ^{03,04}	TC ^{03,04}	M ^{04,05}	E ^{04,05}	TC ^{04,05}	M ^{05,06}	E ^{04,05}	TC ^{05,06}
P5-c	Jun 2006	1.43	1.45	0.99	1.42	1.54	0.80	0.99	1.54	1.15
P3-d	Jun 2006	0.91	0.92	0.99	0.98	2.01	0.80	1.37	2.01	1.15
P2-c	Jun 2006	1.33	1.35	0.99	0.95	1.37	0.80	0.99	1.37	1.15
D2-b,c	Aug 2004	0.98	1.00	0.99	1.21	1.28	0.80	0.99	1.28	1.15
D4	Aug 2004	1.17	1.19	0.99	0.11	0.14	0.80	1.22	0.14	1.15

Goals, Constraints, and Efficiency: Results from a Cluster Analysis

The present section investigates the link between the motivations underlying the purchase of new equipment, the managerial goals and constraints of the heads of units, and the efficiency of the units analysed, as measured by DEA. Given the small number of units under analysis (17, because 2 units were discarded due to incomplete questionnaires), a simple classification of the units under investigation using K-means cluster analysis is presented. The units have been grouped into two clusters. Efficiency scores for 2006 (year in which all the ecographers were already in use) plus alternative blocks of characteristics obtained from the interviews are used as classificatory variables. Three alternative blocks are considered: managerial goals, motivations for purchase, managerial constraints.

Results from the cluster analysis are summarised in Tables 5-7, which show the final cluster centres, the number of units in each cluster and the results of F-tests indicating which variables contribute the most to the cluster solution. Table 3 shows the two clusters resulting from the importance assigned to four managerial goals: maximization of activity levels, economic returns, patient satisfaction, and prestige. Roughly the same number of observations belong to cluster 1 (#9) and 2 (#8). The asterisk signals those features for which the separation between clusters is the greatest (sig < 0.05). Units in cluster 2 assign greater importance to the maximization of

TABLE 3
Clusters according to Managerial Goals

Managerial goals	Cluster	
	1 (#9)	2 (#8)
Activity levels*	3	4
Economic Returns*	2	3
Patient satisfaction	4	4
Prestige*	4	2
Efficiency score 2006	1.12	1.64

Notes: * indicates that the difference between clusters is significant ($p < 0.05$).

activity levels and returns. Nevertheless, their efficiency score is lower than the score of the typical unit in cluster 1, which assigns relatively more importance to prestige. This exploratory analysis suggests that the pursuit of prestige is not at odds with efficiency.

Table 4 classifies units according to the motivations underlying the purchase of equipment. Here the main characteristics of interest are the objective to reduce waiting lists for ecography diagnoses and the pursuit of prestige. Ten units belong to cluster 2 in which prestige and improvement in the quality of service are the motivations deemed most important. As in the cluster analysis reported in Table 4, these units fare slightly better in terms of efficiency scores.

TABLE 4
Clusters according to Motivations for Purchase

Motivations for purchase	Cluster	
	1 (#6)	2 (#10)
Shorten waiting lists*	4	2
Activity levels	3	3
Improve quality of service	5	5
Prestige*	2	4
Reduce unit cost of services	2	1
Efficiency score 2006	1.43	1.36

Notes: * indicates that the difference between clusters is significant ($p < 0.05$).

Finally, a classification has also been attempted in terms of managerial constraints. Results are reported in Table 5. Most units (15 out of 17) belong to the first cluster: for these, the constraints which are felt the most are those pertaining to administration and the availability of personnel, rather than equipment and the type of patient. These units also exhibit a lower technical efficiency.

TABLE 5
Clusters according to Managerial Constraints

Managerial constraints	Cluster	
	1 (#15)	2 (#2)
Type of patient*	2	5
Equipment	3	4
Personnel	4	3
Administration*	4	3
Efficiency score 2006	1.41	1.00

Notes: * indicates that the difference between clusters is significant ($p < 0.05$).

Summing up, the classification into clusters shows that units who assign greater importance to prestige exhibit higher efficiency. This suggests that the quest for prestige is not at odds with efficiency, as the earlier models such as Newhouse (1970), Lee (1971), and Harris (1977) assumed. Instead, prestige may measure the effort towards the provision of more specialised care, and this may translate into higher efficiency. Similar results are reported by the authors (Ancarani, Di Mauro & Giammanco, forthcoming) in a regression analysis using a large number of hospital wards. In particular, the quest for prestige may be at the root of a search for high performing human and physical resources, rather than give rise to over-investment and over-staffing.

CONCLUSIONS

This paper has presented an investigation whose aim was to study at hospital ward level the purchasing process of new equipment and to assess its impact on ward performance. A model of the decision process that leads to the purchase of medical equipment has been developed. The model makes the hypothesis that there are

two actors influencing the acquisition of technology. The General Manager, whose principal goals are efficiency and quality, and the Head of unit with his own goals and constraints, who is the internal customer in the purchasing process.

The empirical analysis of the data supplied by the health organisation under investigation has been carried out in two steps. In a first step, the impact of the technology purchase on technical efficiency scores has been estimated by means of Data Envelopment Analysis. In the period under investigation there is little variation of the efficiency scores for units producing both inpatient and outpatient care, while some of the units producing only outpatient care exhibit greater variability.

Although the lack of availability of data concerning either process or clinical quality prevented us from assessing whether an improvement in outcomes was actually at issue, the productivity analysis showed that some increase in relative efficiency was obtained for most units as a result of the equipment introduction. In particular, this increase took place in the year immediately following the acquisition of the ecographe.

In order to investigate whether the Head of unit's goals, motivations for purchasing and constraints are related to efficiency, a cluster analysis has been carried out. With reference both to the Head of unit's goals and motivations for purchasing, the findings suggest that the pursuit of prestige is not at odds with efficiency, in line with other results in the literature. With reference to the Head of unit's constraints, the analysis outlines the importance of constraints pertaining to administration and the availability of personnel.

The analysis developed was meant to supply a decision aid to the Purchasing Office of the health organisation, adding relevant information to that already collected by the organisation through its standard forms. These forms focused on the growth in the quantity of services or of revenues that the new equipment could bring about, with little attention paid to substitutive or innovative acquisitions which may lead to an improvement of outcome.

Some limitations of this research must be acknowledged. First of all, the small sample size does not allow any generalisation or definite conclusions. Also, lack of data concerning the quality dimension

allows defining performance only in terms of technical efficiency. Further research is needed to address these shortcomings.

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