Public Provision and Performance

Contributions from Efficiency and Productivity Measurement

Edited by Jos L.T. Blank

Social and Cultural Planning Office of The Netherlands

With contributions from C.A. Knox Lovell, Shawna Grosskopf e.a.

2000

ELSEVIER

Amsterdam - Lausanne - New York - Oxford - Shannon - Singapore - Tokyo

tices that might underlie their superior performance, and which might successfully transfer to the Capital Region.

Chapter 14 concludes the book and provides the reader with some retrospections. Five major issues are being discussed. First, it is stressed that the public sector has a large impact on national economy. An efficient public sector may easily improve GNP by more than 5%. Second, much efficiency research has been conducted, but unfortunately has not been implemented. There is only a small number of examples of successfully implementing research outcomes into concrete policy. Third, theories on efficiency measurement contain advanced mathematics and statistics. The lack of transparency of the methodologies used prevents a widespread use of efficiency measurement amongst policy makers and managers. Nevertheless, various examples in the book show the importance of a valid choice of model specification, a valid choice of empirical technique and a proper definition of service provision and resource usage. The cumbersome theories and techniques are more than just scientific hobbyism. Fourth, efficiency analysis can be beneficiary in various ways. It may be helpful in improving managerial processes, but also in determining financing systems, planning of capacities and choosing the right system of property rights. Fifth, much of the validity of the efficiency measurement depends on the data availability. Much improvement can be accomplished in this area, especially where it comes to the measurement of the quality of service provision and the environmental characteristics.

Contents

5 Remedying Excess Capacities in French Surgery Units by Industry Reallocations: The Scope for Short and Long Term Improvements in Plant Capacity Utilization

Benoît Dervaux, Kristiaan Kerstens and Hervé Leleu[1]

5.1 Introduction

Several studies have documented the existence of important overcapacities in the French hospital sector, and especially in specialized care. About 34,000 beds would be redundant in terms of short stay capacity. This amounts to about 15% of total capacity (Guyomar 1995). Despite this surplus in supply, large regional inequalities persist with regard to both the health status of the population and the availability of specialized equipment (Coca 1995).

A plausible underlying mechanism leading to the documented overcapacities is the nature of competition in the health industry. The strategy of hospitals is to enlarge their capacities and their range of services, thereby in general privileging specialized care. This quality competition leads to overcapacities at the industry level (Wooley and Frech 1989).

The recent interest in evaluating efficiency has undoubtedly improved our understanding of plausible mechanisms inhibiting the functioning of public sector institutions. But, most frontier or "best practice" studies have limited themselves to documenting the various inefficiencies in an accurate way. One disadvantage documented in the literature is that production units often object to certain policy decisions made on the basis of these performance results (Epstein and Henderson 1989). Almost inevitably, efficient units remain unaffected, though their performance is only relatively good, while inefficient units are "punished" by, for instance, cutting budgets or being forced to adjust their inputs and outputs to certain observed best practice targets.

This study, by contrast, investigates structural remedies at the industry level. In particular, the study not only documents inefficiencies at the firm level, in our case hospitals. It also looks at remedies by considering reallocations of outputs and inputs among the firms within the same sector. Furthermore, it studies the ideal industry configuration by reporting on the optimal combination of firms meeting actual sector demands and compatible with currently available inputs.

Most performance studies focus on the firm level and use meanwhile well-known, standard frontier methodologies. The evaluation of industry efficiency is less well developed. This contribution extends the seminal work of Färe, Grosskopf, and Li (1992) who develop long-run industry production frontiers. In these long-run industry models, all inputs and outputs can be reallocated with the goal of achieving an optimal industry structure. These models complement the short-run industry production function earlier developed in Johansen (1972). Recognizing that capital is a fixed factor and that most investments take the form of capital goods of a certain vintage, the latter author includes capacity constraints in the industry production function. This implicitly assumes that ex ante, i.e., before the investment decision is taken, the technological choices facing the firm allow for large substitution possibilities between inputs. But once investments have been made (ex post), none or only few substitution possibilities remain in the short run. This is called the putty-clay tradition. The models of Färe, Grosskopf, and Li (1992), by contrast, ignore any capacity limitations. These models can be helpful in reorganizing the health care industry in general. Furthermore, they tend to find solutions that imply savings for the public budget.

These industry production frontiers are extended in several ways. Basically, we modify the models to handle multiple outputs and we eliminate recourse to ad-hoc specifications of production capacity. An ad-hoc specification is, e.g., found in Førsund, Hjalmarsson, and Summa (1996) who apply the short-run Johansen (1972) model. Instead, we adopt the methodology proposed in Färe, Grosskopf, and Kokkelenberg (1989) that provides an operational definition for the plant capacity definition first introduced by Johansen (1968).[2] We are aware of only a handful of applications of these models in general (e.g. Li 1992), including one in the health care industry in particular (Li and Ng 1995).

As stressed by Førsund and Hjalmarsson (1987: 141), the economic relevance of these sector models is that they allow for both a positive and normative interpretation. In their words, these models can either be positively used to "simulate industry behaviour under decentralised decision making" or normatively applied to show "how to organise the industry in the most efficient way".

When considering reallocations among hospitals, we obviously have a normative social planning perspective in mind. In particular, we presuppose that in the short run current market demand can be planned and reallocated among hospitals such that existing capacities are optimally utilized. Industry performance increases mainly by an elimination of technical inefficiencies and by an improvement of capacity utilization rates. In a long run perspective, existing capacities no longer constrain the planning process.

Indeed, according to several specialists the rationalization of supply would allow to: limit the phenomenon of supply-induced demand, exploit more fully returns to scale and economies of scope, economize by grouping reserve capacities, and preserve the quality of care. With respect to the latter, one should notice that guaranteeing a minimal critical mass of interventions allows to fully exploiting learning effects. This has been documented in the medical literature by, for instance, Luft, Bunker, and Enthoven (1979) and Luft, Hunt, and Maerki (1987), among others. In this sense, concentration of activities beyond a minimum level is a necessary condition to assure good quality of care. For instance, a recent French policy measure in this spirit is to close down all maternity hospitals with fewer than 300 births a year.

Since a critical number of interventions is a condition to attain minimal quality levels, we ideally would like to guarantee a minimum level of quality of care in the whole industry. However, no information on quality of care is available. Therefore, the explicit objective of our models is to maximize the savings in all types of surgery rooms. Negatively stated, preventing the use of underutilized surgery rooms cannot decrease the quality of surgical care. Furthermore, as it is widely believed that medical doctors (MDs) are a critical resource, we verify whether or not our primary goal is compatible with the current industry allocation of variable inputs.

This study complements preliminary results with these models reported in Dervaux, Kerstens, and Leleu (1999) in two respects. First, we include personnel information. Earlier, we assumed that the personnel constraint was not binding at the industry optimum. Now we can simply check whether this is the case or not. This is important since a numerus clausus in France, effective since 1978, restrains the supply of MDs in general terms in an effort to limit the supply of health care, and consequently supply-induced demand. Neglecting eventual different needs between disciplines, this quantity constraint recently seems to create shortages for certain specialists. It is a widespread opinion that this shortage explains the inability to fully exploit existing capacities (see, e.g., de Pouvourville 1996). Anticipating our empirical results, we show that the current allocation of MDs is sufficient to face demand.

Second, outputs are slightly aggregated in an effort to counterbalance the reduction in the number of organizations evaluated. The latter is a consequence of a shift in the level of analysis from surgery units to hospitals. We carefully control whether our empirical results remain qualitatively in line with this earlier research. Lacking other studies using similar models, this yields at least one point of comparison to assess the plausibility of our outcomes.

This paper unfolds as follows. The next section provides some background information, including some statistics, on the French health care sector. Section 5.3 starts with a discussion of the firm and industry efficiency models using Data Envelopment Analysis (DEA) techniques. Section 5.4 contains a detailed description of the samples utilized and develops the technology specification for the hospitals. All empirical results are presented in Section 5.5. A final section concludes, formulates critical notes, and suggests some extensions.

5.2 Health Care in France: Background and Statistics

In 1997, health care expenditures represented 9.6% of French GDP, reaching a level of $2,250 in per capita terms. France has among the highest share of health expenditures in GNP compared to OECD countries, only preceded by the United States, Germany and Switzerland. About 47% of the total health budget is devoted to hospital care. In this field, the public sector delivers 70.1% of the industry capacity, conceived in terms of the number of beds. Among private hospitals, a clear distinction should be made between hospitals participating to the public health service (denoted PSPH), counting for 9.1% of the industry capacity, and not-for-profit or for-profit hospitals, respectively 4.3% and 16.3% of the industry capacity.

Despite differences in ownership status, PSPH hospitals are very similar to public hospitals, because they face the same constraints (e.g., obligation to admit any patient at any time) and share the same financing rules. From 1983 to 1996, public and PSPH hospitals have operated under a global budget to cover their operating costs, including MDs wages. Since 1996, a prospective payment system based on Diagnostic Related Groups (DRGs) has been introduced. Private hospitals receive a per diem payment to cover nursing care, medication and catering. They also receive a lump sum for each surgery or delivery so as to finance their capital investments. In contrast to public hospitals, private hospitals are organized as doctors' workshops, since most MDs are independent workers that are paid on a fee for service basis.

This coexistence of two financing schemes leads to huge differences in economic incentives between public and private providers. This undoubtedly adds to the perceived influence of ownership status. Private hospitals are induced to invest in activities where productivity gains are possible though a strategy of specialization and standardization (like surgery and obstetrics). Table 5.1 highlights this phenomenon by presenting the repartition of beds by activity and according to ownership status.

Our study concentrates on the Nord/Pas-de-Calais region. Narrowing the geographical perspective does not change the main features described so far. One exception is that the market share of the private sector in this region is slightly below the national level (29.8% versus 35.4%).

Table 5.1

Repartition of Beds by Activity and Ownership Status (percentages)

	public sector	*PSPH*	*private sector not-for-profit*	*private sector for-profit*
medicine	78.9	7.9	2.1	11.0
surgery	46.2	7.4	3.6	42.8
obstetrics	59.4	4.9	2.7	33.0
rehabilitation care	42.4	21.6	14.9	21.0
long term care	91.8	3.8	3.4	0.9
psychiatry	68.3	15.2	2.6	13.9
total	64.7	10.6	5.1	19.7

5.3 Firm and Industry Efficiency Models

This section first depicts the intuition behind the firm and industry models used in this contribution. Then, these basic models are extended to adopt them to the planning context of the French health care system. Basically, this section provides a non-technical summary of the underlying notions. Appendix A5.1 furnishes a rather detailed numerical example illustrating the basic concepts behind the different models. Details on the required computations are outlined in Dervaux, Kerstens, and Leleu (1999) and can be found in a technical appendix available from the authors on request.

5.3.1 *Methodological Intuition*

A unified methodological framework for measuring firm and industry efficiency been introduced in Sengupta (1991) and refined by Färe, Grosskopf, and Li (1992). These authors bring together two strands of literature. First, they build upon the by now popular literature focusing on assessing firm performance. This literature is associated with the seminal contribution of Farrell (1957) and is reviewed by Lovell (1993). Second, a somewhat smaller series of articles and books concentrate on modeling industry production functions and sector efficiency. The main contributions here are probably the Aigner and Chu (1968) and Seitz (1971) articles and the Johansen (1972) and Førsund and Hjalmarsson (1987) books.

These technologies of firms and industries are constructed from data on organizations or decision making units (DMUs) by imposing appropriate assumptions. Reasoning in a multi-input multi-output framework, a combination of different types of inputs is used to produce a combination of different types of outputs. A production possibility or transformation set represents the set of all feasible input-output combinations (see Section 2.2 of this volume). For our application, it is essential to distinguish between fixed and variable inputs.

At the firm level, one of the basic technologies is a constant returns to scale model. This technology, that actually imposes some additional conditions, has been presented in Appendix A2.1 and is also repeated in an Appendix available upon request (or see Färe, Grosskopf, and Lovell (1994)). The main motivation for this model is that it is linked to the long run competitive ideal of a zero-profit equilibrium. Industry specifications of technologies are derived from the above firm-based technologies by considering all inputs and outputs available in the sector as simultaneously reallocatable. This contrasts with firm efficiency models whereby none of the observed inputs and outputs of the individual firms can be reallocated among other firms.

Frontier methods require not only a specification of technology, but also some concept of distance to the frontier. The output measure of efficiency is defined as a factor indicating the largest feasible extension of the current outputs, while maintaining constant input levels. It is positive and bounded below by unity. The unit value is obtained when the observation is producing efficiently. A value greater than unity indicates the possible percentage increase in outputs given current input levels. It also has a straightforward revenue interpretation.

This output oriented efficiency measure is mainly introduced to explain the notions of plant capacity and plant capacity utilization below. In the empirical section, we employ both output- and input-oriented efficiency measures (see Section 2.2 of this volume). The first to determine current hospital plant capacity utilization and the technology at full capacity, the latter to operationalize our main objective of minimizing the use of surgical rooms.

We now turn to the notion of plant capacity at both the firm and the industry level. Following the definition of Johansen (1968), plant capacity is the maximal amount that can be produced per unit of time with existing plant and equipment without restrictions on the availability of variable production factors.[3] Plant capacity utilization (PCU) is then measured as a ratio of current, but technically efficient, outputs to the maximal outputs according to the above definition. To avoid confusing technical efficiency and incomplete plant capacity utilization, Färe, Grosskopf, and Kokkelenberg (1989) have devised a procedure using efficiency measures to separate both notions in a frontier context. An observation is first evaluated in terms of technical efficiency to a standard technology. Then, the same observation is compared to a plant capacity technology, i.e., the same technology but without restrictions on the availability of variable inputs. Details on the required computations are outlined in Dervaux, Kerstens, and Leleu (1999).

Having defined all the elements for our analysis, our modeling strategy can be summarized as follows. First, starting from observed inputs and outputs at the firm level we determine the plant capacity for each firm using an output oriented efficiency measure. These computations are instrumental to determine the maximum production capacities at the firm level, and, implicitly, at the industry level. Then, switching to an industry perspective, we look for a reallocation of the total amount of fixed inputs and outputs in the industry relative to a full plant capacity technology in two ways. First, we minimize proportionally the use of fixed inputs in a short run perspective, that is, given existing plant capacities. Second, we pursue the same objective function but disregarding existing plant capacities. This amounts to allowing a rescaling of existing plant capacities. All these steps in our procedure are summarized in Table 5.2. Observe that variable inputs never constrain the solution of the optimization problems, but are part of the decision variables. We check afterwards whether there are sufficient variable inputs to satisfy the demands resulting from the optimal solutions.

The Appendix A5.1 develops two numerical examples to illuminate the basic notions underlying our analysis.

Table 5.2

Summary of Models

	orientation	outputs	fixed inputs	variable inputs
firm PCU	output	firm allocation	firm allocation	free
industry: current PCU	input (fixed)	industry allocation	industry allocation	free
industry: rescaling of PCU	input (fixed)	industry allocation	industry allocation	free

5.3.2 *Model Refinements: Adaptation to French Planning Context*

To account for the planning context of French health care, our model diverges from the above described classical ones in three ways.[4] First, we include an emergency constraint when determining plant capacities at the firm level. The emergency nature of certain surgical interventions tends to decrease technical efficiency as well as capacity utilization, since these cases are very demanding in terms of organizational flexibility (Friedman and Pauly 1981). Of course, a minimum number of hospitals (most often public ones) should remain open at night to assure proper treatment of the uncertain demand related to emergency cases. In our model, we impose that the reference hospital at the frontier treats at least as many emergency patients as the evaluated hospital.

Second, we take into account the organizational structure of supply and demand in the Nord/Pas-de-Calais region. The northern hospital regulation agency (ARH) distinguishes between four areas ("bassins de vie") in this region: Littoral, Lille, Hainaut and Artois. Each of these areas defines a geographical entity with homogenous socio-cultural characteristics and a great similarity in the demand for health care. The long-term goal of the ARH is to organize health care supply in such a way that population needs in each area can be covered. Therefore, in the industry models we impose that local demand is met in each of the four areas of the Nord/Pas-de-Calais region.

Third, having mentioned the problem of regional disparities in health care access in the introduction, an open question is whether there are also phenomena of suppressed demand in the four sub-regions of Nord/Pas-de-Calais. As a matter of fact, the Nord/Pas-de-Calais region is known to be under-equipped compared to national standards (see Coca 1995). This is important given the policy objective of ARH to refine the structure of health care supply so as to cater for geographically heterogeneous population needs. Therefore, we also estimate a theoretical demand for surgical interventions using national data. Details of the procedure are outlined in Section 5.5.2.

5.4 Surgery in French Hospitals

5.4.1 *Sample Description*

We use two data sets for this study. Our principal data source is a census of all surgery units in France operating in 1992 conducted by the French social security. A total of 1,605 hospitals have been surveyed. Our study concentrates on a sub-sample of 92 hospitals situated in the northern part of France (Nord/Pas-de-Calais region). This census gathered information at four distinct tiers: the hospital level; all surgical wards; all surgery units within each hospital; and a sample of surgical interventions drawn for each surgery unit. This data set still offers the most comprehensive picture of surgical activity and equipment available today in France. Unfortunately, data on personnel (MDs, nurses, nursing aids,...) is not available. To overcome this drawback, we extract information on staff numbers from an administrative survey of all private and public hospitals annually organized by the Ministry of Health since 1994. In this second data source, personnel numbers are, however, only available at the hospital level, not at any of the tiers underneath.

Clearly, there is a discrepancy of two years between both data sources. This forces us to assume that no drastic personnel changes have occurred between 1992 and 1994. Furthermore, due to the need to match two data sets at different levels of aggregation, we have been obliged to work at the level of the hospital. Our earlier study focused instead at the surgery unit. Since fewer units of analysis remain, we are also forced to aggregate somewhat our definition of outputs. This is the only way to escape the curse of dimensionality inherent in non-parametric frontier analysis. Unfortunately, no standard test procedures are available to guide us in this modeling effort (though see Banker (1996) for some recent proposals).

The two data sets have been matched by looking at the number of surgical beds available in each hospital in 1992 and 1994. The concatenation of both data sources has been impossible for four small hospitals, which reduces the sample size from 92 to 88 hospitals. Furthermore, surgical activities are not equivalently defined in the two data sets. To maintain consistency, we have reallocated staff from obstetrical to surgical wards according some specific rules. Details on the matching procedure are given in Appendix A5.2.

A final challenge is that personnel need not exclusively be dedicated to surgical interventions as such. MDs, but especially nurses and nursing aids may have other activities in, for instance, surgical wards. In the second data source, there is no information on the precise repartition of time between surgical interventions and surgical wards. We have to find ways to account for the time devoted in surgical wards so as to avoid specification bias. First, we include the total number of inpatient days in surgical wards as an additional output. Second, we also include the number of beds in surgical wards as an additional input. Thus, our specification of technology no longer narrowly focuses on surgical interventions, but is enlarged to include related activities of personnel in surgical wards.

5.4.2 *Model Specification*

Turning to a description of surgical technology, we sequentially devote our attention to its outputs, and then its fixed and variable inputs. Starting with the outputs, we distinguish surgical acts by their nature and complexity. Regarding their nature, acts are grouped according to a successive combination of two criteria: first, classical surgery versus exploratory acts, and subsequently bone surgery versus visceral surgery. Regarding their complexity, acts are classified according to a French index based on surgical standards (denoted ICR). This index summarizes the complexity of each surgical act and is constructed from judgements of medical experts regarding the necessary resources under ideal circumstances. We partition surgical activity into heavy, medium and light surgical acts.[5] Theoretically, the combination of the classifications according to nature and complexity yields 12 (4x3) categories. However, in practice certain categories are empty and so we end up with six types of surgical activities. In addition to these outputs, we have isolated endoscopic activity, since this is the most frequently observed surgical activity. In fact, this sole act accounts, on average, for about 17% of total surgical interventions. Finally, for reasons explained in the previous subsection, we also included total inpatient days in surgical wards. This leads to a total of eight output categories. Note that regrettably we have no information on the quality of surgical interventions or on the quality of care in surgical wards.

There are three kinds of inputs in our model: the number of surgery rooms per kind; the number of beds; and personnel per category. Surgery rooms are considered as fixed inputs, since they imply huge investments and most, if not all, of these costs are sunk. Beds and personnel, by contrast, are variable input categories, since they can be allocated in different ways at little cost. Before discussing each of these inputs in turn, we first contrast our view of beds as variable inputs to the tradition to regard them as a fixed input when analyzing hospital efficiency. The goal of our analysis is first and foremost to evaluate surgical activity within hospitals. Therefore, surgery rooms, due to their sunk costs, are the fixed factors on which our analysis sheds light: should one maintain a surgical activity in this hospital or not, and if so at what level? Beds in surgical wards

depend only partially upon the activity of the surgery unit, since they can be easily recycled for other purposes. Therefore, they are variable dimensions for our purpose.

Surgery rooms differ mainly in their fixed equipment and, consequently, in the types of acts that can be performed while guaranteeing minimal quality standards. The survey distinguishes between seven types of rooms: from nursing rooms to highly specialized rooms dedicated to cardiology and neurology (precise definitions are found in Table A5.2). We aggregate type D and E rooms, since only one hospital in the region has a type E room. Thus, our analysis ends up with six room types.

Regarding the variable inputs, we include the number of beds in surgery wards. Furthermore, full time equivalent personnel information is classified according to three types: MDs, nurses, and nursing aids. Descriptive statistics on outputs, surgery rooms, beds and personnel categories are found in Table 5.3.

Clearly, most interventions (about 60%) are classified under the medium visceral and light surgery categories. Few hospitals (only 28%) engage in heavy exploratory acts. Turning to the inputs, 67% of fixed inputs fall under the B and C categories, representing the standard surgery rooms. Rooms of type G are sparsely available in the region. Note also that the distributions of some of the inputs and outputs have a wide range and are highly skewed, exemplifying the size differences between the various hospitals.

5.5 Firm and Industry Efficiency: Empirical Results

5.5.1 *Industry Level Results*

First, the current situation is characterized in terms of plant capacity utilization. For each firm (hospital), we compute the plant capacity utilization model.[6]

Table 5.3 also summarizes the results for this PCU firm model. It turns out that, at full capacity, hospitals could raise their outputs by 15% on average. Moreover, 59 of the 88 hospitals (67 %) operate at full capacity. We also compare initial and optimal numbers of rooms as well as the initial and optimal outputs. In line with previous results (see Dervaux, Kerstens, and Leleu 1999), inefficiencies are mainly found in surgery rooms with below average equipment (type A rooms) and with rather standard surgery acts (light surgery and medium visceral surgery). When operating at full capacity, the surgery industry could raise its activities by at least 10%.

Table 5.3

DESCRIPTIVE STATISTICS ON OUTPUTS AND INPUTS AND PCU RESULTS

	mean	st. dev	max.	% zeros	total	PCU	%[a]
outputs							
heavy surgery	220	640	5,930	10	19,400	22,400	15
heavy exploratory acts	90	490	4,510	72	8,010	8,830	10
medium bone surgery	660	820	6,400	0	57,700	65,600	14
medium visceral surgery	1,780	1,840	15,500	0	156,000	195,000	25
light exploratory acts	420	980	8,720	9	36,600	41,800	14
light surgery	1,540	1,610	12,400	0	135,000	172,000	27
endoscopy	970	2,180	15,300	16	85,400	97,300	14
inpatient days	25,500	28,200	252,000	0	2,240,000	2,550,000	12
fixed inputs							
room B	1.7	4.6	41	43	145	145	0
room C	3.5	4.3	38	10	306	306	0
room D, E	0.8	1.6	10	59	71	70	1
room A	0.6	0.8	4	57	49	34	29
room F	0.9	2.4	20	63	79	74	6
room G	0.3	0.8	5	83	23	22.7	1
total rooms	7.6	12.0	113	0	673	653	3
variable inputs							
medical doctors	10.3	14.9	138	0	905	949	-5
nurses	44.4	89.9	827	0	3,910	3,920	0
nursing aids	52.3	99.9	919	0	4,610	4,530	2
beds	94.1	128	1,120	0	8,280	8,670	-5

a *Excess or shortage capacities as a percentage of initial endowments.*

Turning now to the industry analysis, Table 5.4 provides results for the input efficiency measure computed on the fixed inputs solely for both the short-term Johansen model and the long-term model. Compared with the current situation, it reveals the excess capacities in the fixed inputs. In both models, the optimal number of rooms is estimated by a maximal contraction of the input vector, eventually diminished by the slack variables. The main conclusions are as follows. First, at the industry level, rooms can be reduced by about 15% in the short-run and even by 29% in the long-term. Like in the PCU firm model, the largest overcapacities are situated in surgery rooms with below average equipment (rooms of type A and F).

Table 5.4

AVAILABLE AND OPTIMAL OUTPUTS AND INPUTS IN THE INDUSTRY MODELS

		short-run model		long-run model	
	total	number	%[a]	number	%[a]
outputs					
heavy surgery	19,400	20,400	5	19,400	0
heavy exploratory acts	8,010	8,600	8	9,200	15
medium bone surgery	57,700	59,700	3	58,500	1
medium visceral surgery	156,000	175,000	12	198,000	26
light exploratory acts	36,600	38,800	6	53,000	44
light surgery	135,000	152,000	13	191,000	41
endoscopy	85,400	87,200	2	100,000	18
inpatient days	2,240,000	2,240,000	0	2,240,000	0
fixed inputs					
room B	145	126	13	107	26
room C	306	266	13	225	26
room D, E	71	62	13	52	26
room A	49	30	39	28	44
room F	79	68	14	52	34
room G	23	19	16	17	26
total rooms	673	571	15	480	29
variable inputs					
medical doctors	905	833	8	777	14
nurses	3,910	3,500	10	3,020	23
nursing aids	4,610	4,000	13	3,040	34
beds	8,280	7,590	8	7,230	13

a *Excess or shortage capacities as a percentage of initial endowments.*

These estimated overcapacities for the Johansen model are exactly the same as in Dervaux, Kerstens, and Leleu (1999), but they are about 18% less in the long-term model. The different level of aggregation in both studies probably explains this difference. In the first article, these models were solved at the surgery unit level, while the present work has been obliged to focus on the hospital level. While outputs have been aggregated, this does not seem to have counterbalanced the above shift in perspective.

Results for the optimal variable inputs are also presented in Tables 5.3 and 5.4. For all models, we calculate optimal quantities of personnel and beds for hospitals at full capacity utilization. Starting with the PCU firm model in Table 5.3, we notice that the initial allocation of nurses and nursing aids is just sufficient to meet the optimal number of variable inputs necessary at full capacity. By contrast, the actual numbers of MDs and beds in the sector are insufficient to respond to demand at full capacity. Turning to the short- and long-term models, we see that, by contrast, the actual allocation for the industry is sufficient (Table 5.4). Allowing for reallocation, the demand could be largely met with current variable input endowments. At the very minimum in the short-run model, there is even an 8% excess of MDs and beds. Though its is equally clear that the latter two variable input dimensions appear to be, relatively speaking, the most constraining in all three models.

5.5.2 *Results for the Four Sub-regions*

Table 5.5 reports the structure of results for short- and long-run models for the four areas, i.e., the optimal values for the activity vector. Accounting for the organizational structure of supply and demand in the Nord/Pas-de-Calais region, local demand is met in each area in the optimization problems. In the short-run model, 72% of hospitals operate at full capacity instead of the 67% currently. 16% produce below full capacity and 12% have a zero optimal activity. The latter implies stopping activities in the surgery units of these hospitals. Closing down hospitals is not at stake. Results are rather homogeneous for these four areas.

In the long-run model, scaling surgery units within hospitals up or down is allowed. The latter obviously encourages reallocations between hospitals. Now only 23% (= 17% + 6%) of hospitals, or rather scaled up or down versions of current units, are needed to produce the industry output. The latter results show the normative aspect of the long-term model. In each area, more than two-thirds of hospitals transfer their surgical activity to these scaled units. A detailed look at the empirical results reveals that indeed the surgery units with a mix similar to the industry mix are scaled up, while more specialized units are either eliminated or used to complete the industry needs.

A problem is that surgical activities in some hospitals are scaled up rather drastically. For instance, one unit in the sample is scaled up by a factor smaller than 18. This scaling of a current full capacity technology raises a methodological issue concerning the feasibility and usefulness of the resulting optimal activity vector. First, taken literally as scaling up the surgical activities of an existing unit, it raises questions about the technological and medical feasibility. Second, a more plausible interpretation is that it indicates the optimal duplication of this existing plant. In the latter case, about 18 other units (not in table) should be structured and organized similar to this optimal unit. Since all cannot possibly be attached to the same hospital, their exact location remains an open issue. By contrast, the short-run plant capacity model has the advantage of imposing less assumptions, since only a scaling down or up of activities within a unit with existing capacity is feasible.

Table 5.5

Structure of Reallocations in the Four Areas

		short-run model			long-run model		
	number of hospitals	% full capacity	% below full capacity	% zero capacity	% of scaled hospitals		% zero capacity
					up	down	
Littoral	18	67	28	5	22	0	78
Lille	26	70	15	15	15	4	81
Artois	22	82	14	4	18	9	73
Hainaut	22	68	9	23	14	9	77
total	88	72	16	12	17	6	77

For these areas, we actually consider three models: in addition to the classical Johansen and long-term models, we also develop a long-term model with an estimated instead of observed demand. To estimate population needs in surgery, we employ the observed national rates of surgical interventions in each of our 7 output categories per age and per sex. These rates are used to compute a theoretical demand in each area according to its own population structure in terms of age and sex. The final output, inpatient days, is corrected by regressing this variable on a constant and the total number of surgical interventions at the national level. Results for these computations are reported in Table A5.3. Summarizing, the deviations between estimated and current outputs reveal that the Lille sub-region has a surgical activity largely exceeding its needs. By contrast, Artois and Hainaut seem to be deprived of interventions in many of the output categories.

Table 5.6 presents the optimal number of rooms in Littoral, Lille, Artois and Hainaut. In the short-run model, Lille and Artois, with the largest current endowments, show the least overcapacities in rooms (respectively 12% and 11%). The reverse results are, however, obtained in the long-run model (respectively 31% and 33%). The two others regions have about the same amount of excess rooms under both models (between 21% and

24%). The structure of results changes drastically when we consider estimated instead of observed demand. Overcapacities in Lille reach 42%, since the observed demand is larger than the estimated one. Results are less pronounced for Littoral, though there are still overcapacities. For Hainaut and Artois, results change both quantitatively and qualitatively. While they experienced overcapacities with observed demand, the new results clearly indicate that they are just about sufficiently equipped or even lack a few rooms.

Table 5.6

Available and Optimal Number of Rooms for the Four Areas

	initial situation	short-run model		long-run model observed demand		long-run model estimated demand	
		number	%[a]	number	%[a]	number	%[a]
Littoral	124	97	21	95	23	107	14
Lille	284	250	12	197	31	164	42
Artois	149	133	11	100	33	153	-3
Hainaut	116	91	22	88	24	118	-2
total	673	571	15	480	29	543	19

a Excess or shortage capacities as a percentage of available rooms.

Table 5.7 presents optimal variable inputs for the estimated demand model. MDs seem to be the critical resource to respond to estimated demand. While abundantly available in Lille, they are a scarce resource for Artois and Hainaut.

Table 5.7

Initial and Optimal Number of Variable Inputs: Estimated Demand Model

	medical doctors			nurses			nursing aids			beds		
	obs.	opt.	%[a]	obs.	opt.	%[a]	obs.	opt.	%[a]	obs.	opt.	%[a]
Littoral	183	170	7	686	584	15	945	650	31	1,580	1,310	17
Lille	412	295	28	1,810	916	49	1,170	921	48	3,100	2,350	24
Artois	169	232	-37	803	584	27	1,020	1,080	-6	2,080	2,310	-11
Hainaut	141	170	-21	611	526	14	866	675	22	1,520	1,340	12
total	905	868	4	3,910	2,610	33	4,610	3,330	28	8,280	7,310	12

a. Excess or shortage of staff and beds as a percentage of initial endowments.

These areas need an additional 37% respectively 21% of their current allocation of MDs to respond to population needs. At the regional level, MDs are just sufficient to cover surgical needs. Furthermore, only Artois has an insufficient number of beds in the long run. Again, Lille shows structural excess capacities for all types of personnel and beds.

5.6 Conclusion

For policy purposes, the following tentative conclusions can be formulated. Our empirical results highlight existing overcapacities in French surgery. The use of our industry reallocation models at full plant capacity reveals that about 15% of surgery rooms can be closed down while satisfying the regional demand for health care in the short run. In the long run, overcapacities reach even up to 29%. The number of MDs is sufficient at the regional level to meet current and even estimated health care demand, at least after reducing surgical capacities in specific hospitals. A comparison with our previous work shows that these results appear quite robust with regard to both the definition of outputs and inputs, and the level of analysis.

As to geographical distribution, overcapacities exist in all areas within the Nord/Pas-de-Calais region and mainly affect rooms with below average equipment. They appear slightly more important in Littoral and Hainaut. This picture changes sharply when considering the needs of the population instead of observed demand. In this case, most of the overcapacities are concentrated in Lille and, to a lesser extent, in Littoral. Other areas seem, on balance, to be justly equipped. To cope with these equity concerns, it is necessary to rather drastically reallocate medical labor between areas.

The data coming from two data sets, we have taken great care to match information on personnel with the main census. But, measurement errors on variable inputs cannot be excluded. Nevertheless, these limitations must not be overemphasized, since the variable inputs do not constrain the computations of plant capacities. As a matter of fact, personnel is always a decision variable at the firm level. It is only at the industry level that personnel becomes critical in verifying whether the optimal amounts needed can be met with the actual allocation of resources. Optimal versus actual endowments are checked for both the region and the sub-regions. This comparison shows that concerns about a scarcity of MDs seem premature.

From a methodological point of view, the short-run plant capacity model has the advantage of imposing the least hypotheses. The usefulness of the long-term model requires further investigation, since it assumes that a scaling of a current full capacity technology is feasible and useful. As indicated in the text, there is a question of interpretation of the optimal activity bundle.

It is, however, good to point out two caveats. First, reallocation of inputs and outputs may imply certain adjustment costs. For instance, if one closes down a surgery unit, then this implies writing off large amounts of sunk costs. Equally so, personnel that may be reallocated to other units may face both monetary costs and social stress. Adjustment costs are, however, not explicitly modeled at this stage. A counter-argument is that at least the short-run industry models need not imply irreversible decisions. E.g., if the model results dictate that one should no longer use a specific surgical room, this decision can be undone at a later stage.

Second, concentration of activities, an almost unavoidable result in these models, could be interpreted to imply a shift from social to private costs. That is, a reduction of the public sector health budgets is counterbalanced by increased costs for private users. For instance, a user pays more transportation costs, as average distances increase due to concentration, to undergo a surgical intervention, as will his family members paying him a visit. But, such eventual shift in costs should be weighted against the private and social benefits in terms of improved quality of care. Balancing these gains and losses ideally requires a full-fledged cost benefit analysis, which is for example done by Merkies in Chapter 8. However, this is beyond the scope of our contribution. Furthermore, we believe these costs are no major drawback, since surgery in most cases does not correspond to a recurrent need.

In conclusion, we believe these empirical results underscore the huge policy potential of these industry reallocation models. We hope to apply similar policy-oriented models shortly to the Picardie region. Let us finish by pointing out some further refinements. Clearly, in reality some demands should be met at the local level, while others could better be treated at the regional or even national level. This requires the introduction of nested or hierarchical levels. This is not impossible in a frontier context, as shown in Athanassopoulos (1998) and illustrated in Dervaux, Kerstens, and Leleu (1999). Finally, the link between our long-term plant capacity model and the more traditional Färe, Grosskopf, and Li (1992) models remains to be explored.

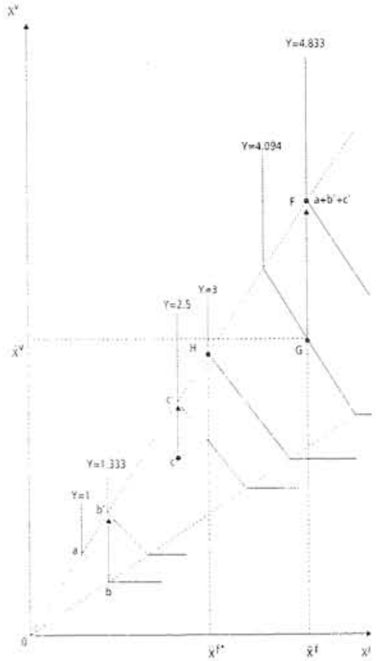
Appendix

A5.1 Numerical Examples

This subsection develops two numerical examples to illuminate the basic notions underlying our analysis. We start by explaining the plant capacity concept: first at the firm level and then at the industry level. Then we develop the industry frontiers with and without capacity constraints.

The plant capacity concept is explained in Figure A5.1 using a simple numerical example (see also Table A5.1).

Figure A5.1
Plant Capacity at the Firm and Industry Level



The sector includes three firms, represented by points a, b and c, producing a same output from different endowments in variable and fixed factors. The x-axis represents fixed inputs, the y-axis variable inputs. The technology exhibits constant returns to scale. This shows up by the rays from the origin to the efficient points on the frontier. This ray implies that the efficient point can be completely scaled up or down without restrictions. Thus any proportional increase in all outputs can be obtained by simply increasing all inputs by that same proportion. Firms a and b are efficient, whereas firm c uses too much of each input. It can be calculated that its output efficiency score is 0.48.

Table A5.1

Numerical Examples

	output	*fixed input*	*variable input*	*te*	*% pcu*
numerical example 1					
firm a	1	3	3.5	1	100
firm b	1	4	2	1	75
firm c	1	7.5	5.5	0.48	84
total industry	3	14.5	11	0.73	85

	variable input/ output	*fixed input 1*	*fixed input 2*	*te*	*% pcu*
numerical example 2					
firm a	1	1	6	1	100
firm b	1	5	1	1	100
firm c	1	3	2	1	100
firm d	1	3	5	0.73	100
total industry	4	12	14	0.84	100

The technology used by firm a can be seen to be the least intensive in terms of the fixed factor compared to the processes employed by firms b and c. When the firms are unconstrained in terms of their variable input, it is firm a and all of its extensions along the ray oa that guarantee a maximal output. Thus, it is somewhere along this ray oa that all firms reach their full plant capacity. Firm a then operates at full capacity by definition. Firm b, by contrast, could produce a greater quantity of output given its current level of fixed input. Moving point b to the ray oa (i.e., vertically onto point b') yields an output equal to 1.33 (larger than the current unit output). Having determined the maximal output at full plant capacity, one can compute the plant capacity utilization rate of firm b as the ratio of its current output divided by this output at full plant capacity. Firm b thus currently produces at 75% of its plant capacity (=1/1.33). Computations for firm c proceed along the same lines, but with the complication that we first have to remove the technical inefficiency. First, we project this observation onto the frontier into the output direction (not visible on Figure A5.1). When being efficient, point c could produce 2.09 output units. Second, moving this frontier projection vertically towards c' yields an optimal capacity output of 2.5 units. Thus, the plant capacity utilization rate of firm c is about 83.8% (=2.09/2.5). Notice that capacity utilization rates are indeed computed at the frontier, to avoid any confusion with the technical efficiency notion.

To determine the capacity for the whole industry, we first observe that the industry allocation simply equals the sum of all inputs and outputs of the firms in the industry (point G). Industry capacity output now corresponds to moving this allocation onto the ray oa (i.e., point F). This full capacity output equals 4.83 (=1+1.33+2.5). This number corresponds exactly to the sum of the individual firm's capacity output levels. Notice that, geometrically speaking, point F is simply the sum of the line pieces oa, ob' and oc'. Furthermore, line piece GF equals the sum of the line pieces bb' and cc'. The latter simply correspond to the additional variable inputs necessary, both at the individual and industry level, to be able to produce at full plant capacity. This summing property illustrates that the Johansen measure of plant capacity is consistent for sector aggregation. Current industry output equals 3 (= 1+1+1). If one eliminated the inefficiency of firm c, the industry could at best attain an output level of 4.09 (= 1+1+2.09). Thus, the capacity utilization rate at the industry level is 84.7% (= 4.09/4.83).

To illuminate the difference between firm models and the short-run industry frontier, we carefully indicate their production possibilities using the same numerical example. This reveals what one can expect when one

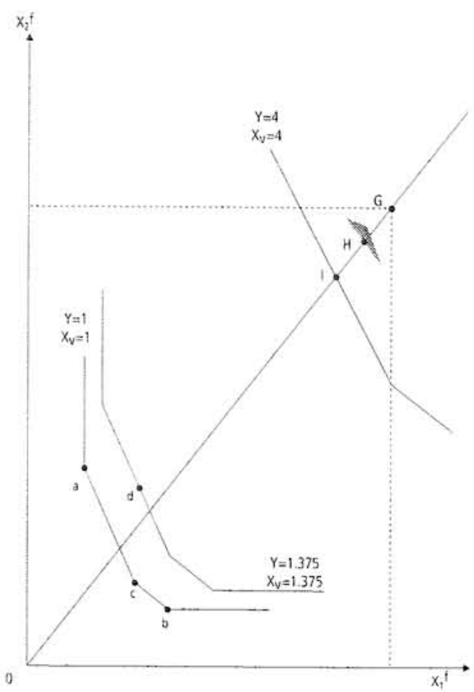
either cannot or can reallocate inputs and outputs among firms in an industry. Since our empirical study considers demand as exogenous, we seek to find the minimal quantity of fixed inputs compatible with the actual industry output and using the full capacity production plans a, b' and c'. In Figure A5.1, the solution of this problem is located at the intersection (point H) between ray oa and the isoquant corresponding to the current industry output.

Notice that, as in the PCU firm model, variable inputs do not constrain the optimal solution, since they are decision variables. However, we may face scarce resources at the industry level. In fact, two situations can occur. On the one hand, this solution point may be compatible with the current total endowment of variable inputs in the industry. Hence, current fixed inputs and optimal variable inputs can produce the optimal industry output. On the other hand, optimal variable inputs may exceed the available industry allocation. In this case, if one cannot procure the necessary additional variable inputs, then it is impossible to produce the optimal industry output from the full capacity production plans.

Turning to the distinction between short- and long-term industry models, we need to introduce a second numerical example where four firms use two fixed inputs as well as one variable input to produce a single, identical output (see again Table A5.1). Production possibilities at full capacity are presented in Figure A5.2.

Figure A5.2

Short- and Long-run Industry Models



Twelve units of fixed input 1 and 14 units of input 2 produce 4 units of output. The current industry allocation for both fixed inputs is again indicated by point G. In the long run, efficient production with industry output 4 is feasible. A projection of point G onto the industry isoquant yields intersection point I, with an efficiency score of 0.84. The short-run Johansen production model has a feasible set represented by the grayed region. This set is determined by all combinations of the four individual firms yielding an industry output of 4, while respecting the capacity constraint. Minimizing the use of fixed inputs, the projection of point G onto this feasible set leads to point H with efficiency score 0.91. Clearly, for the same output level, the short-run model requires more of both fixed inputs, resulting in less optimal savings at the industry level. Intuitively stated, the mechanism behind this result is that the long-run model can scale both up and down initial capacities in its search for an industry optimum. The short-run model, by contrast, can only maintain existing full capacities or scale them down.

Readers who are interested in details on the required models and computations are referred to a technical appendix that is available from the authors upon simple request.

A5.2 Definitions and Descriptive Statistics

The two data sets have been matched by looking at the number of surgical beds available in each hospital in 1992 and 1994. Most regional hospitals show no change in capacity during this time period. On average, the number of surgical beds in the Nord/Pas-de-Calais region decreased only by 3% between both years. The concatenation of both data sources has been impossible for four small hospitals, because they closed down surgical units during this two years period. But, these four hospitals represented altogether less than 1.5% of the industry capacity in the region. This reduces the sample size from 92 to 88 hospitals. Furthermore, surgical activities are not equivalently defined in the two data sets. In the census, part of the obstetrical activity (like caesarian sections) is considered as surgical, while the administrative survey uses a more traditional etiological distinction between obstetrics and surgery. To maintain consistency, we reallocate staff from obstetrical to surgical wards in proportion to the percentage of obstetrical beds considered as surgical in the census.

Table A5.2

Definition of Surgery Rooms

1. type b rooms: simple equipment for basic surgical acts
2. type c rooms: standard equipment suitable for the most common surgical acts
3. type d rooms: aseptic rooms with high air quality control
4. type e rooms: specialized rooms devoted to cardiology and neurology
5. type a rooms: nursing rooms
6. type f rooms: rooms for endoscopy
7. type g rooms: radiological intervention rooms

Table A.5.3

Observed and Estimated Demand for Surgical Activities for the Four Areas

	Littoral			Lille			Artois			Hainaut			total region		
	obs.	est.	%	obs.	est.	%	obs.	est.	%	obs.	est.	%	obs.	est.	%
heavy surgery[a]	3.9	2.0	49	6.2	11.1	-79	6.0	3.7	37	4.0	2.5	37	20.1	19.4	4
heavy exploratory[a]	0.9	0.6	34	1.4	5.9	-316	1.4	1.2	12	0.9	0.3	73	4.6	8.0	-73
medium bone surgery[a]	11.9	13.6	-15	19.2	20.9	-9	17.4	12.7	27	11.7	10.5	10	60.2	57.7	4
medium visceral surgery[a]	32.9	31.3	5	53.0	57.7	-9	47.8	39.1	18	32.3	28.3	12	165.9	156.4	6
light exploratory[a]	8.7	5.9	32	14.0	20.6	-48	12.7	5.1	60	8.6	5.0	42	43.9	36.6	17
light surgery[a]	27.5	28.0	-2	44.7	50.9	-14	38.8	28.8	26	26.2	27.3	-4	137.2	135.1	2
endoscopy[a]	22.1	16.8	24	35.1	38.9	-11	33.3	24.0	28	22.4	5.7	75	112.9	85.4	24
inpatient days[b]	440	421	4	828	676	18	583	612	-5	433	415	4	2.284	2.111	8

a Demand expressed per 1.000 acts of surgery.

b Demand expressed per 1.000 inpatient days.

Notes

[1] Keywords: firm efficiency; plant capacity; short and long run industry efficiency; reallocation; hospitals. We thank H. Allemand (CNAMTS) for authorizing the use of the "GAIN Chirurgie" survey as well as B. Colladon and B. Vincke (ENSM) for their medical expertise at an early stage of this study. Our conclusions do not reflect official positions of CNAMTS nor ENSM. This research benefitted from financial support from the Ministry of Work and Social Affairs (MIRE convention N° 31/95). The comments of J. Blank are gratefully acknowledged.

[2] See Färe, Grosskopf, and Valdmanis (1989) for an application in the health care sector.

[3] This technical or engineering notion of capacity utilization can be contrasted to other cost-based notions of capacity utilization (see Johansen 1968 or Morrison 1985).

[4] The reader can consult Dervaux, Kerstens, and Leleu (1999) for technical details on the first two issues.

[5] We retain two thresholds: one at 25 and another at 100 ICR points.

[6] We follow the standard two-stage procedures of Ali and Seiford (1993). First, the plant capacity is determined by optimizing a radial output efficiency measure. Second, the sum of residual slacks is maximized, taking account of the optimal adjustment of outputs from the first stage.

References

Aigner, D., and S. Chu. 1968. On Estimating the Industry Production Function. *American Economic Review* 58 (4): 826-839.

Ali, A., and L. Seiford. 1993. The Mathematical Programming Approach to Efficiency Analysis. In: Fried H., C.A.K. Lovell, and S. Schmidt (eds.), *The Measurement of Productive Efficiency: Techniques and Applications*. Oxford: Oxford University Press, 120-159.

Athanassopoulos, A. 1998. Decision Support for Target-Based Resource Allocation of Public Services in Multiunit and Multilevel Systems. *Management Science* 44 (2): 173-187.

Banker, R. 1996. Hypothesis Test Using Data Envelopment Analysis. *Journal of Productivity Analysis* 7 (2-3): 139-159.

Coca, E. 1995. *Les inégalités entre hôpitaux. Obstacle à l'efficacité et à l'équité de la maîtrise des dépenses hospitalières*. Paris: Berger-Levrault.

de Pouvourville, G. 1996. L'héritage. In: Contandriopoulos, A-P., and Y. Souteyrand (eds.), *L'hôpital stratège: Dynamiques locales et offre de soins*. Paris: John Libbey, 271-283.

Dervaux, B., K. Kerstens, and H. Leleu. 1999. Rationalisation de l'offre de soins en chirurgie: Réduction des surcapacités et réallocation sectorielle. *Revue Economique* 50 (3): 645-655.

Epstein, M., and J. Henderson. 1989. Data Envelopment Analysis for Managerial Control and Diagnosis. *Decision Sciences* 20 (1): 90-119.

Färe, R., S. Grosskopf, and E. Kokkelenberg. 1989. Measuring Plant Capacity, Utilization and Technical Change: A Nonparametric Approach. *International Economic Review* 30 (3): 655-666.

Färe, R., S. Grosskopf, and S-K. Li. 1992. Linear Programming Models for Firm and Industry Performance. *Scandinavian Journal of Economics* 94 (4): 599-608.

Färe, R., S. Grosskopf, and C.A.K. Lovell. 1994. *Production Frontiers*. Cambridge: Cambridge University Press.

Färe, R., S. Grosskopf, and V. Valdmanis. 1989. Capacity, Competition and Efficiency in Hospitals: A Nonparametric Approach. *Journal of Productivity Analysis* 1 (2): 123-138.

Farrell, M. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society Series A: General* 120 (3): 253-281.

Førsund, F., and L. Hjalmarsson. 1987. *Analyses of Industrial Structure: A Putty-Clay Approach*. Stockholm: Almquist & Wiksell.

Førsund, F., L. Hjalmarsson, and T. Summa. 1996. The Interplay between Micro-Frontier and Sectoral Short-Run Production Functions. *Scandinavian Journal of Economics* 98 (3): 365-386.

Friedman, B., and M. Pauly. 1981. Cost Functions for a Service Firm with Variable Quality and Stochastic Demand: The Case of Hospitals. *Review of Economics and Statistics* 63 (4): 620-624.

Guyomar, C. 1995. Comment mesurer les capacités excédentaires dans les hôpitaux? *Solidarité Santé* 4: 9-16.

Johansen, L. 1968. Production Functions and the Concept of Capacity, Namur, Recherches Récentes sur la Fonction de Production (Collection «Economie Mathématique et Econometrie», n° 2) reprinted in Forsund, F.R. (ed.), *Collected Works of Leif Johansen*, Volume 1, Amsterdam, North Holland, 359-382).

Johansen, L. 1972. *Production Functions: An Integration of Micro and Macro, Short Run and Long Run Aspects*. Amsterdam: North Holland Publishing Company.

Li, S-K. 1992. Three Essays on Efficiency Measurement. Carbondale (IL): Southern Illinois University (PhD dissertation).

Li, S-K., and Y.C. Ng. 1995. Measuring the Productive Efficiency of a Group of Firms. *International Advances in Economic Research* 1 (4): 377-390.

Lovell, C.A.K. 1993. Production Frontiers and Productive Efficiency. In: Fried, H., C.A.K. Lovell, and S. Schmidt (eds.), *The Measurement of Productive Efficiency: Techniques and Applications*. Oxford: Oxford University Press, 3-67.

Luft, H.S., J.P. Bunker, and A.C. Enthoven. 1979. Should Operations Be Regionalized? The Empirical Relation between Volume and Mortality. *New England Journal of Medicine* 301 (25): 1364-1369.

Luft, H.S., S.S. Hunt, and S.C. Maerki. 1987. The Volume-Outcome Relationship: Practice-Makes-Perfect or Selective-Referral Patterns? *Health Services Research* 22 (2): 157-182.

Morrison, C. 1985. Primal and Dual Capacity Utilization: An Application to Productivity Measurement in the U.S. Automobile Industry. *Journal of Business and Economic Statistics* 3 (4): 312-324.

Seitz, W. 1971. Productive Efficiency in the Steam-Electric Generating Industry. *Journal of Political Economy*, 79 (4): 878-886.

Sengupta, J.K. 1991. Farrell Efficiency: Some Generalizations and Econometric Implications. In: Kaul, T., and J. Sengupta (eds.), *Economic Models, Estimation, and Socioeconomic Systems: Essays in Honor of Karl A. Fox*. Amsterdam: Elsevier, 125-140.

Wooley J.M., and H.E. Frech. 1989. How Hospitals Compete: A Review of the Literature. *Journal of Law and Public Policy* 2 (1): 57-79.

6 Efficiency of Dutch Nursing Homes: The Sensitivity of DEA-scores to Different Sets of Resource Prices

Evelien Eggink and Jos L.T. Blank[1]

6.1 Introduction

The Dutch nursing home industry is currently the subject of a great deal of public interest because expenditures on nursing home care are large, have increased significantly over the past 20 years, and are expected to continue increasing in the future because the population is growing older. Real expenditure on nursing home care in the Netherlands increased from 2.8 billion guilders in 1974 (0.7% of GNP) to 5.9 billion guilders in 1997 (0.9% of GNP).[2] Most important, the homes are reimbursed almost entirely from government sources.

Nursing home efficiency is important to both policy makers and management. Policy makers can use this information to introduce more incentives in the reimbursement scheme or change regulations in order to cut budgets without affecting the level and quality of services. Management of nursing homes can benefit from efficiency analyses by changing the production process in order to save costs and assure continuity.

The primary objective of this chapter is to examine the efficiency of the Dutch nursing home industry, using the method of Data Envelopment Analysis (DEA). Efficiency scores are calculated for each nursing home. Mean efficiency scores and variation in efficiency scores are presented. Further, differences in efficiency scores are analyzed by viewing the relationship with background characteristics of individual nursing homes. Such relationships are of interest to managers and policy makers since they yield insight into the causes of inefficiency. Stability of such relationships is required in order to take effective policy measures. These relationships are estimated in a second step using regression analysis.