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ON USING SUPER-EFFICIENCY OF DATA ENVELOPMENT ANALYSIS IN DRUG ELUTING STENT (DES) IN TAIWAN

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Abstract:

In order to balance the trade-off between medical quality and cost reduction, hospitals have to keep making critical decisions on choosing a best cost-effectiveness of hospital materials. This study aims to develop approaches for the evaluation of drug eluting stent (DES). Since it is a multi-criteria decision-making problem, we first screen the indicators as "cost", "in-stent restenosis", "quantity" and "profit". We proposed to evaluate the indicators by super-efficiency of data envelopment analysis (DEA). The proposed approaches are able to acquire a ranking of the cost-effectiveness of DES. Following our case study, we conclude that the proposed approaches may serve as more objective and effective decision-making tool for the decision-makers.

Keywords: drug eluting stent (DES), super-efficiency, data envelopment analysis (DEA)

INTRODCUTION

The development and research in health care industry has constantly created new medical devices which provide more therapeutic effects and lower side-effects than former medical devices. For example, the drug-eluting stent (DES) has significantly changed the world of clinical percutaneous coronary intervention (PCI). A dramatic reduction of in-stent restenosis (ISR) when compared to a bare-metal stent (BMS) prompted an explosive number of DES implantations. But the problem is that the new medical devices are more expensive. In order to balance the trade-off between medical quality and cost reduction, hospitals have to choose between the former medical devices and the new ones. In Taiwan, the review mechanism for new medical devices is always–decided by the medical device committee of the hospitals. Besides, the evaluation is relied only on the judgment of the commissioners, without a formal guideline. Moreover, almost all commissioners of the medical device committee of most hospitals are physicians. When the physicians review the new medical devices, they usually judge according to their professional background, and the therapeutic effectiveness is the main consideration. This may create a heavy financial burden to the hospitals. The primary aim in this study was to establish an objective and efficient decision-making procedure that consider both treatment effect and cost for the medical devices to be purchased.

METHODOLOGY

Pareto optimality is the most favorable rating method to the objective, and many appraisal methods have been developed from this concept. The relative efficiency of analysis and comparison of the assessment for multiple units and options is proposed by Charnes et al. (1978) and Banker et al. (1984), which is called data envelopment analysis (DEA). DEA is a non-parametric, linear programming based technique for measuring the relative efficiency of homogeneous units that consume incommensurable multiple inputs and produce multiple outputs. The method chooses "efficiency" as the main concept to make the sum mode, and the attribution is divided

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into two parts: inputs (the attributes which have the negative effects to the target), and outputs (the attributes which have the positive influences to the target). The inputs and outputs are assumed to be continuous positive variables and the weights are estimated in favor of each evaluating unit to maximize its efficiency. DEA achieves to classify the units into efficient units that achieve efficiency scores equal to the upper bound and inefficient units that are those that do not succeed to do so. DEA is a widely accepted evaluation method by researchers and practitioners because it has repeatedly proved its ability to effectively handle multiple conflicting properties associated with the modern requirements of administrative sciences.

DEA is a mathematical model that measures the relative efficiency of decision-making units with multiple inputs and outputs but with no obvious production function to aggregate the data in its entirety. Relative efficiency is defined as the ratio of total weighted output to total weighted input. By comparing n units with *s* outputs denoted by Y_{rk}; r = 1,……, *s*; and *m* inputs denoted by X_{ik} , i = 1,……,*m*; the efficiency measure for DMU *k* is

$$Max \qquad h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

The efficiency ratio ranges from zero to one, with DMU *k* being considered relatively efficient if it receives a score of one. Thus, each unit will choose weights so as to maximize self-efficiency, given the constraints.

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \; j = 1,....,n$$

$$u_r, v_i \ge \varepsilon > 0, r = 1,...., s; i = 1,...., m$$

The result of the DEA is the determination of the hyperplanes that define an envelope surface or Pareto frontier. DMUs that lie on the surface determine the envelope and are deemed efficient, whilst those that do not are deemed inefficient. The formulation described above can be translated into a linear program, which can be solved relatively easily and a complete DEA solves n linear programs, one for each DMU.

$$Max \qquad h_k = \sum_{r=1}^{s} u_r y_{rk}$$

Subject to:

$$\sum_{i=1}^{m} u_r x_{ik} = 1,$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \le 0, \; j = 1,....,n$$

$$u_r, v_i \ge \varepsilon > 0, r = 1,...., s; i = 1,...., m$$

The basic DEA results group the DMUs into two sets, those that are efficient and define the Pareto frontier and those that are inefficient. In order to rank all the DMUs, another approach or modification was required. Andersen and Petersen (1993) developed a new procedure for ranking efficient units, the super-efficient methodology in which DMUs are ranked through the exclusion of the unit being scored from the DEA dual LP. The methodology enables an extreme efficient unit k to achieve an efficiency score greater than one by removing the kth constraint in the primal formulation. as shown in model

$$Max \qquad h_k = \sum_{r=1}^{s} u_r y_{rk}$$

Subject to:

$$\sum_{i=1}^{m} u_r x_{ik} = 1,$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \le 0, \; j = 1,....,n$$

$$u_r, v_i \ge \varepsilon > 0, r = 1,...., s; i = 1,...., m$$

The dual formulation of the super-efficient model, as seen in model (9), computes the distance between the Pareto frontier, evaluated without unit k, and the unit itself i.e. for $J = \{ j = 1,\ldots,n;\; j \neq k\}$

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$$Min \quad f_k$$

Subject to:

$$\sum_{j \in J} L_{kj} x_{ik} \leq f_k x_{ik}$$

$$\sum_{j \in J} L_{kj} y_{rk} \geq y_{rk}$$

$$L_{kj} \geq 0$$

$$i = 1,\ldots,m; r = 1,\ldots,s; \; j = 1,\ldots,n \, ,$$

DEA is mainly used in the performance evaluation research of the hospital in the healthcare system. For example, Ferrier and Valdmanis (1996) estimated the operating efficiency of hospitals in U.S. based on CCR and BCC models, and concluded that profit hospitals were more efficient than nonprofit hospitals and public hospitals. Chang (1998) used CCR, BCC models to evaluate the operating efficiency of six public hospitals in Taiwan. Puig-Junoy (2000) used CCR, BCC and the A&P models to assess the efficiency of 94 hospitals which treat the serious disease in Spain, and to explore how hospital environment affects on the efficiency. O'Neill and Dexter (2005) compared two techniques for increasing the transparency and face validity of Data Envelopment Analysis (DEA) results for managers at a single decision-making unit: multifactor efficiency (MFE) and non-radial super-efficiency (NRSE). They compare results for operating room managers at an Iowa hospital evaluating its growth potential for multiple surgical specialties. Dexter and O'Neill (2008) used resampling of data to explore the basic statistical properties of super-efficient data envelopment analysis (DEA) when used as a benchmarking tool by the manager of a single decision-making unit. Zanboori et al (2014) Calculated super efficiency of DMUs for ranking units in data envelopment analysis based on SBM model

First, we define the problem, and clarify the relative performance evaluation purposes. Then, we establish the goals by setting the evaluation criteria to determine the input and output attributes, and produce homogeneous decision making units as performance evaluation—for comparison and data collection. In this study, for example, within the same pharmacological classification of all drugs, are objects being evaluated, also known as "decision-making units" (DMU). Secondly, we obtained DEA model construction efficiency border, and compared the actual performance of decision-making unit with efficiency border to measure the efficiency and analyze results to see if the decision-making unit is efficient. For efficient decision-making unit, we further examined its robustness, and then chose the most efficient decision-making units according to the result.

RESULTS

This study uses six kinds of drug eluting stent for effectiveness evaluation in treating coronary artery disease (CAD) (the code DES-1,…., DES-6 use to replace its original name). Evaluation of relative efficiency of the option with DEA method must be built on the relative performance data of every input or output attributes of each decision-making unit, therefore, all the attributes that affect cost-effective, including cost (input), in-stent restenosis rate (input), quantity(output) and profit (output). First, we collect relevant data. The collected data is listed in table I. Second, the DEA analysis program was using Efficiency Measurement System (EMS) v1.3 software and executed. The results are shown in table II. DES-6 was ranked as the most effective DES as determined by the four indicators (cost, in-stent restenosis rate, quantity and profit) , followed by DES-3, DES-4, DES-1, DES-5 and DES-2.

Table I: The indicators of DES

DMU	Cost (NTD$)	In-stent restenosis (%)	Quantity (per month)	Profit (NTD$)
DES-1	54150	0.09	1	19850
DES-2	57000	0.06	5	17000
DES-3	55100	0.04	13	18900
DES-4	53200	0.08	1	20800

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DES-5	58000	0.04	12	16000
DES-6	55000	0.03	12	19000

Table 2: The result of super-efficiency

DMU	Score	Rank
DES-1	93.81%	4
DES-2	80.71%	6
DES-3	108.14%	2
DES-4	107.54%	3
DES-5	89.04%	5
DES-6	134.04%	1

DISSCUSSIONS

In the past, the cost-benefit analysis usually depended on pharmacoeconomics approach, which is based on the analysis of the effectiveness of costs and benefits of the target to the overall healthcare system (Townsend, 1987). The pharmacoeconomics approach focuses on recognition, measurement and comparison of treatment costs (resource consumption) and treatment results. The evaluation methods include cost-effectiveness analysis, cost-benefit analysis, cost-minimization analysis and cost-utility analysis (Willet et al, 1989; Bootman, 1991), which do not include multiple considerations. In addition, the results of these analyses may be affected by the rank and position of the decision makers, and thus subject to challenge.

The medical devices selection by physicians is a professional decision-making process, it must reflect the subjective value of judgments. Under the premise to achieve high quality and low cost target of hospital. The evaluation model proposed in this research allows the decision-making units to find their best weight, to enhance the efficiency of the decision-making unit as much as possible, the weights derived by DEA method in this study exclude the subjective influence. This overcomes the shortcomings of subjective influence in pharmacoeconomics methods. When evaluating the indicators, we seek for measurable basis from the professional judgments.

The difference between DEA method and other multi-criteria decision-making analysis model is that you do not have to define the relative weights of attributes, because the relative weights are generated by the empirical data in DEA method. Therefore, the efficiency of each option is measured by the set of weights, which is the most optimal for the option, and also avoids subjective judgments of the decision makers. If we choose the same set of weights to measure all of the options in the physicians' position, the treatment effect would be given more weight; in the hospital managers' position, it might be replaced with profit, and in the manager's position, factors such as amount of inventory cost may be taken into consideration. Therefore, DEA model has a relatively fair basis under different conditions by the evaluation options.

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