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A measure of the performance of a Hospital - A Micro-based analysis

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ABSTRACT

Micro-economic foundation of a hospital's optimal resource allocation is discussed in addition to the foundation of a quantitative method to evaluate the performance of a hospital depending on pure economic definition of the efficiency. This study is important for scholars and practitioners in the field of hospitals management and economics because it provides simple micro-economic foundation of this subject.

KEYWORDS: hospital management, economics of hospitals management, efficiency analysis, data envelopment analysis, production functions, firm behaviour, optimal allocation of resources

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I. INTRODUCTION

This manuscript presents the micro-economic foundation of a hospital's optimal resource allocation in addition to the foundation of a quantitative method to evaluate the performance of a hospital depending on a pure economic definition of the efficiency. The manuscript is important for scholars and practitioners in the field of hospitals management economics because it provides simple micro-economic foundation to this subject. This manuscript does not aim to review previous literature in this regard but rather it aims to present simply the micro-economic foundation of the optimality concept of hospitals' resource allocations as a foundation to the understanding of the concept of the efficiency within a simple quantitative framework.

This manuscript does not aim to provide a real example of any hospital but rather it provides a simple approach that depends on microeconomic analysis of optimal allocation of resources in a hypothetical hospital so to be a guide to scholars and practitioners for further applied research works in this regard.

The manuscript includes four sections; section II after the introduction presents the micro- economic foundation of a hospital's resources allocation. Section III presents a simple quantitative method to measure the performance of a hospital depending on a pure-economic definition of the concept of the efficiency. The conclusion follows section III.

II. The Understanding of a Hospital's Production Function and Micro-economic Foundation of a Hospital's Resource Allocation

The production function of a hospital shows a relation between the medical services as a dependent variable from one side and the different inputs as independent variables from the other side as explained by Mervio (2013), Siebert and Zubanov (2010) and ossialos, Naci and Chandra (2012). Those inputs are the physicians, the experts, the nurses, workers, the medical equipment, the location of the hospital, its surrounding utilities, its entertaining facilities, in addition to the shareholders. All those inputs are not identical or homogenous and even each input separately is not homogenous but they differ in their degrees of qualifications, skills, experiences, etc. Therefore; we can divide the production factors that produce each unit of the medical services to:

- Resources encompass the nursing staff, the physician staff, the experts, the workers, the managers with different degrees of skills, qualifications, experiences, etc.
- The natural resources encompasses the land of the hospital, its premises, its geographical location, its gardens and entertaining facilities, and hospitality facilitates and utilities.
- Physical capital resources encompass the medical equipment and essential tools.
- Financial capital resources encompass the financial assets of the medical institution as an investing institution or common public shares as a public medical institution. Other types of resources, medical supplies and pharmaceutical supplies.

The pricing strategies of all those resources and their different allocations are determined by the following determinants:

- The nature of the hospital; if it targets profits or public benefits.
- The degrees of the competitions of the markets of the production factors and the characteristics of the resources.
- The degrees of the integration of the production input with the other inputs and the degrees of its integration with the output of the medical service (s) as well and the pricing strategies of the final output.
- The external factors encompasses the bylaws, legislations, the business cycles of the industry and of the whole economy, the relevant social factors, the relevant political factors and the process and the environment of the decision making in addition to the degrees of the recognition of others' rights and the optimal allocation of resources over generations. This manuscript discusses those external factors that we call the non- economic factors or determinants of the optimal allocation of the production factors. The following section differentiates between the economic factors and the non-economic factors that affect the optimal allocations of the resources of a hospital. The Difference between the economic and the non-economic factors that affect the optimal allocation of a hospital's resources:

The economic factors of the optimal allocations of resources:

- The economic factors that determine the optimal allocation of the production factors of the medical service (s) depends on the characteristics of the hospital if it purely targets the maximization of the profit or if it targets the public benefits. If we assume that the hospital targets the maximization of the profit; then the degree of the link between the optimal pricing and the optimal allocation of the resources depends on the pricing strategy of

the final medical Service (s) of the hospital that is strongly related with the degree of the integration of those resources as well. The determination of the medical service final pricing that is originally determined on the base of the maximization of the profit cannot be separated from the principle of the maximization of the quality of the medical service, which, in turn, cannot be achieved but through an optimal integration of all inputs. On the other hand, if the hospital does not aim the maximization of the profit but it rather aims the public interest then, the optimal allocation of resources here is determined by different social, legislative, and political factors; whereas the economic factors have the lowest share among the other factors in their effect on the optimal allocation of resources. Those other factors that affect the optimal allocation of the resources in a public hospital will be discussed in a following section.

- The production function of a hospital that aims for maximizing profits takes the following implicit formula:

The target function of this for profit hospital takes the following formula;

The cash flows of the profits = the discount factor. (The cash flows of the total resources - the payments flows of the total costs)

The discount factor is usually determined on the base of the interest rate that takes the inflation rate into account.

Symbolically; the production function of a private hospital can take the following formula:

$$Y = f(X_1, X_2, X_3, X_4, X_5)$$

Where; Y refers to the final medical service (s), x_1 refers to the human resources that encompasses the nursing staff, the physicians staff, the managers the other workers, etc., x_2 refers to the physical capital such that the medical equipment and tools, x_3 refers to the natural resources encompassing the geographical location of the hospital and the comfort, the hospitality and the entertaining facilities in addition to the internal and the external gardens of the hospital, x_4 refers to the financial assets of the owners and stakeholders of the private hospital, and x_5 refers the other medical supplies and the pharmaceutical supplies. The technological factor is not considered a separate factor in this function but it is augmented into all the 5 broad factors in the right hand side of the above function. Each input's main units are not identical or homogenous but they differ according to the characteristics of each unit.

The payment to those production factors is the cost of the production of the final medical service that its pricing strategy depends on the following determinants:

- The cost of the production factors that is determined itself by many factors such that the degrees of the scarcity and the required qualifications and skills and the degree of its integration with the other inputs and with the final output.
- The quality standards that largely affect the pricing strategy of the final medical service(s) and can be achieved by the optimal integration of the production inputs so it cannot contradict the principle of profit maximization that is strongly related with the minimization of the total cost at a specific level of a qualified medical service (s).
- Thus, in the case of a private hospital the market has the power in determining the optimal pricing strategy. If the inputs are homogenous which is not the case in our analysis, the marginal cost of each input will equal its marginal product but in the case of the medical service(s), the inputs are not homogenous and hence the marginal cost largely depends on the personal skills of negotiations that depend themselves on demands and supplies powers but from a different approach. For example, if we need to hire a surgeon who has a scarce high skill, the negotiation in determining his/ her salary would be different and it will mainly depend on the hospital's need to his/ her skills in addition to other determinants. The equilibrium here will happen when the negotiated deal is met and the hiring contract is signed by both sides; the hospital and the surgeon. Therefore, each production factor has its own market in an industry that has such unique characteristics like the medical industry. The monopsonist can have the highest possible price in this market. The assumption of the rationality still holds in each negotiated contract because the overpricing is a waste of persistent opportunities.

On the other hand; the pricing goes lower and lower for inputs with lower integration degrees with the rest of inputs and with the final output. Thus, the question of the optimal allocation of production factors payment is related to the power of the market of each input. Hence, the market is responsible here for the optimal allocation of payments. The optimal solution of the following problem achieves such optimality in payments allocations:

Max. The quality of the medical service (S) = f(X_1, X_2, X_3, X_4, X_5) Subject to

- A specific level of the total costs
- The integration degrees among all inputs
- The integration degrees between the inputs and the output

The integration degrees depend on the cross-correlated coefficients of the inputs and on the correlated coefficient of each input and the final output.

To reach the optimality of payments allocations and to the maximum profit as well, the regression of the above production function and the best fit model that controls for all proposed constraints should give the estimators of the correlated coefficients accurately. The highest cross- correlated coefficient gives an indicator for the most important input in the production process and hence its payment is determined rationally through such optimization strategy.

The other factors of resources allocations:

If the hospital does not aim the maximization of the profit but it aims the maximization of the public benefit as the case of a public hospital, then the allocation of the resources here does not depend on the power of the markets but in many cases; the final medical service(s) could be even provided for free or it could be highly subsidized by the government. Because of the scarcity of the economic resources allocated to produce the medical service(s), the optimality of the allocation of those resources are very important to preserve the public wealth of the whole society and for generations ahead. Depending on that logic, the production function of a public hospital that aims for the public interest takes implicitly the following formula:

The maximization of the cash flows of the social welfare over time = the discount factor (the cash flows of the gross social benefits over time – the cash flows of the gross social costs over time.

The optimal allocation of resources can be achieved at the lowest level of the discounted social costs by the dollar today at a specific level of the production quality of the medical service(s).

This specific level of the quality is determined by different factors. If the society is politically matured and democratic; the quality of the medical service likes many other public services is determined by the free democratic election since the public service(s) providers work for the public benefits and hence they abide by the public's collective agreements to guarantee political stability for their parliamentary seats. Yet, in a less democratic – less politically matured society - the public service(s) is usually determined at a lower level than the desirable level by the society because of the lack of the public's censorship and the lack of the public's power. Therefore, the optimality of the allocation of the resources in a public hospital is more feasible in a democratic society than a less democratic society.

On the other hand, the public benefit is a function of quantity of the goods and the services acquired by beneficiaries over time, among those services the medical services. In order for those benefits to reach to their target beneficiaries, legislations and laws take place to maintain a recognized level of the allocation of the limited resources that can lower the effectiveness of the market powers if the optimal allocations were left to the free market to achieve.

Setting legislations cannot guarantee the effective execution of those legislations. This is why in many countries, and because of the absence of the free market powers to determining the optimality, the corruption takes place and instead of allocating social benefits to the target beneficiaries, the wealth can be concentrated on public services providers themselves. This is why the social costs that takes into account not only the financial cost but also the opportunity loss for the society exceeds the social benefits that takes into consideration positive externalities. Hence, instead of maximizing the social welfare, the main aim of establishing public hospitals, the public fret would be aggravated and transmitted to everywhere in the country which can explain reasons for political unrest because of social unrests.

Thus, because of enforcing pricing strategies in both the costs side and the production of the medical service side by legislations, the power of the free market would be obstructed and hence the market will suffer from many distortions and the black markets will dominate all transactions. Also, because the incentive payments system is also obstructed in a distorted mechanism, surgeons and the rest of the medical crew could fail in providing a qualified medical service which can lead to an increase in the mortality rate in public hospitals which can aggravate the social costs much more.

In a more matured - more rational society - the optimal allocations of resources is left to the power of the free market to determine and then the medical service(s) can be subsidized via a well-organized insurance system adopted by the government or by giant insurance companies. Those types of subsidies could be financed by taxes payers which can create a fair system of wealth allocations and income redistribution. Mervio (2013), David, Jenkins, Cooke and Moriton (2004) and Amelung (2013).

III. Evaluating the Performance of Hospitals : Data Envelopment Analysis (DEA)

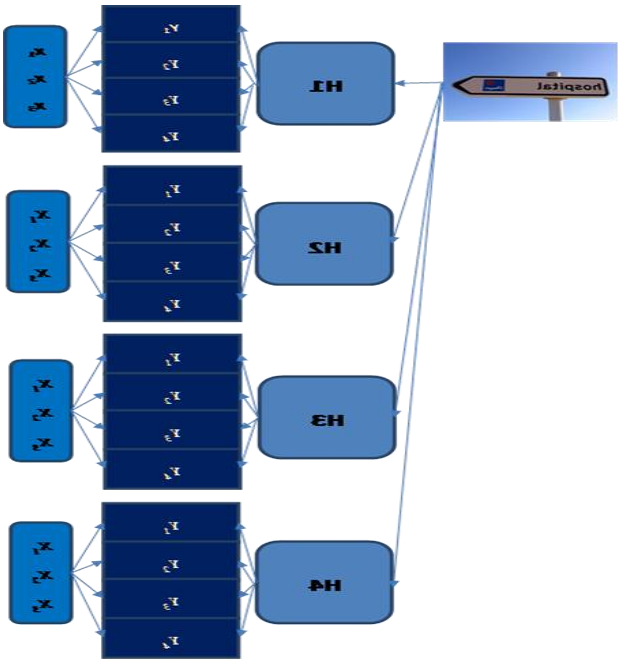
This section addresses the evaluation of the performance of a hospital(s) by utilizing a simple application of linear programming that can be used to measure the relative efficiency of operating hospitals' different departments that have same objectives. The DEA is a simple application of linear programming that's well recognized to measure quantitatively the relative efficiency as just mentioned above. In this regard; this manuscript depends on the description of the linear programming solving techniques and their main concepts from quantitative methods books of business.

The utilization of the **Management Scientist Software Package** for solving the mathematical linear programming models is recommended in this regard. This section simply explains steps of using the DEA in evaluating the relative performance of hospitals. Anderson, Sweemey, Williams, Camm and Cocham (2012).

Recalling the production function of the previous section;

where Y is the medical service(s) and Xs are the inputs needed to produce a unit of Y. Consider that the hospital in question includes 4 main medical departments, H_1, H_2, H_3, and H_4, that have same objective which is providing a high quality of 4 different medical services they provide, Y_1, Y_2, Y_3, and Y_4. Considering that in order to provide those 4- final medical services they need 3 grouping inputs, X_1, X_2, and X_3. The following figure shows the description of this hospital in notational terms

Figure 1: A description of a hypothetical hospital



IV. HOSPITAL

We need now to evaluate the relative efficiency of each department relative to the rest of departments in this described hospital. Consider hypothetical figures for each department's outputs and inputs. Inputs would be denominated by dollars, by beds, or by person within the period of measurements. Outputs would be denominated by inpatients, outpatients, hours, or trainees if the hospital provides medical training as well.

In order to evaluate the relative efficiency for any of the 4- departments, we must have a standard to measure upon. Here, we can consider a composite hypothetical department, H_c, to evaluate the relative efficiency depending on its performance. We calculate numbers of the inputs and the outputs of this composite department depending on the weight average of the 4- departments.

u_1 = *weights applied to inputs and outputs for* H_1
u_2 = *weighs applied to inputs and outputs for* H_2
u_3 = *weights applied to inputs and outputs for* H_3
u_4 = *weights applied to inputs and outputs for* H_4

where; $u_1 + u_2 + u_3 + u_4 = 1$

Let us also consider now that H_1 is the department that we need to measure its relative performance here.The output of the composite department, H_c can be computed by using the following formula;

$$Yc = \lambda_1 u_1 + \lambda_2 u_2 + \lambda_3 u_3 + \lambda_4 u_4$$

where u_1 is the denomination of Y_1, u_2 is the denomination of Y_2, u_3 is the denomination of Y_3, and $u_4$is the denomination of Y_4. Where Y_1, Y_2, Y_3, and Y_4 are the outputs of H_1, the department that we need to measure its relative performance.

On the other hand, the input of the composite department, H_c can be computed by using the following formula;

$$Xc = \beta_1 u_1 + \beta_2 u_2 + \beta_3 u_3 + \beta_4 u_4$$

where u_1 is the denomination of x_1, u_2 is the denomination of x_2, u_3 is the denomination of x_3, and $u_4$is the denomination of x_4. Where x_1, x_2, x_3, and x_4 are the inputs of H_1, the department that we need to measure its relative performance.

The question now is that how we can evaluate the relative performance of H_1, the department in question relative to the composite department H_c. To answer this question, we can use two criteria of measuring the relative performance, one on the outputs side and the other criterion is on the inputs side as follows:

If the output for the composite department, $H_c \geq$ the output of the department in question, H_1, and if the inputs of the composite department, $Hc \leq$ the resources available to the composite department, Hc, then we can claim from 1 and 2 that the composite department, Hc is relatively more efficient than the department in question, H_1, because for the same level of output or a higher level of output it can use less amounts of the inputs. Accordingly, the efficiency of H_1 is relatively less than the efficiency of Hc.

If we apply the output criterion #1, we can have then the following **4-** output constraints in our model because we assume 4- outputs in our model;

$$\lambda_{11}\, u_1 + \lambda_{12}\, u_2 + \lambda_{13}\, u_3 + \lambda_{14}\, u_4 \geq \lambda_{11}$$
$$\lambda_{21}\, u_1 + \lambda_{22}\, u_2 + \lambda_{23}\, u_3 + \lambda_{24}\, u_4 \geq \lambda_{21}$$
$$\lambda_{31}\, u_1 + \lambda_{32}\, u_2 + \lambda_{33}\, u_3 + \lambda_{34}\, u_4 \geq \lambda_{21}$$
$$\lambda_{41}\, u_1 + \lambda_{42}\, u_2 + \lambda_{43}\, u_3 + \lambda_{44}\, u_4 \geq \lambda_{21}$$

where, u_1 is the denomination *of* Y_1 of H_1, and so on. The right-hand-side of each of the above 4- constraints refers to the 4-outputs of the department in question, H_1, whereas the left-hand-side of the above 4-constraints refer to the weighted averages of the 4-outputs for the composite hospital, H_c.

By applying the input criterion #2, the following 3-constraints can be found which satisfy criterion #2;

$$\beta_{11}u_1 + \beta_{12}\, u_2 + \beta_{13}\, u_3 + \beta_{14}\, u_4 \leq \beta_{11}E$$
$$\beta_{21}u_1 + \beta_{22}\, u_2 + \beta_{23}\, u_3 + \beta_{24}\, u_4 \leq \beta_{12}E$$
$$\beta_{31}u_1 + \beta_{32}\, u_2 + \beta_{33}\, u_3 + \beta_{34}\, u_4 \leq \beta_{13}E$$

where; β_{11} is the denomination of first input of the first department and β_{21} for example is the denomination of the first input of the second department and so on. The left-hand-side of the above three inputs constraints refer to the inputs for the composite department whereas the right- hand-side is the resources available to the composite department. E is the fraction of the department in question, H_1's input available to the composite department and it is supposed to represent the efficiency measure as well.

Now, we can set the entire DEA model where the objective function is to minimize the value of E. Accordingly,

If $E = 1$, we can conclude that the department in question, H_1 is not inefficient because the composite department requires as much inputs as the department in question.

If $E < 1$, we can conclude that the department in question, H_1 is judged relatively inefficient because the composite department requires less inputs to make the same level of output achieved by H_1.

Thus, the DEA Linear Programming Model to evaluate the efficiency of the department in question, H_1, can be written as follows:

Min E Subject to:

$$\lambda_{11}\, u_1 + \lambda_{12}\, u_2 + \lambda_{13}\, u_3 + \lambda_{14}\, u_4 \geq \lambda_{11}$$
$$\lambda_{21}\, u_1 + \lambda_{22}\, u_2 + \lambda_{23}\, u_3 + \lambda_{24}\, u_4 \geq \lambda_{21}$$
$$\lambda_{31}\, u_1 + \lambda_{32}\, u_2 + \lambda_{33}\, u_3 + \lambda_{34}\, u_4 \geq \lambda_{21}$$
$$\lambda_{41}\, u_1 + \lambda_{42}\, u_2 + \lambda_{43}\, u_3 + \lambda_{44}\, u_4 \geq \lambda_{21}$$

$$\beta_{11}u_1 + \beta_{12}\, u_2 + \beta_{13}\, u_3 + \beta_{14}\, u_4 \leq \beta_{11}E$$
$$\beta_{21}u_1 + \beta_{22}\, u_2 + \beta_{23}\, u_3 + \beta_{24}\, u_4 \leq \beta_{12}E$$
$$\beta_{31}u_1 + \beta_{32}\, u_2 + \beta_{33}\, u_3 + \beta_{34}\, u_4 \leq \beta_{13}E$$
$$E, u_1, u_2, u_3, u_4 \geq 0$$

We have then the objective function in addition to 9 constraints according to the DEA in this described case. We have 4 output- constraints, 3 input-constraints, the average weights constraint and finally the non-negative constraints of the decision variables. All denominations are known and the only decision variables that we need to figure out their values are. We can reduce the above DEA Linear Programming Model to set the right-hand-side of the inputs constraints to zeroes as follows:

Min E Subject to:

$$u_1 + u_2 + u_3 + u_4 = 1$$
$$\lambda_{11}\, u_1 + \lambda_{12}\, u_2 + \lambda_{13}\, u_3 + \lambda_{14}\, u_4 \geq \lambda_{11}$$
$$\lambda_{21}\, u_1 + \lambda_{22}\, u_2 + \lambda_{23}\, u_3 + \lambda_{24}\, u_4 \geq \lambda_{21}$$
$$\lambda_{31}\, u_1 + \lambda_{32}\, u_2 + \lambda_{33}\, u_3 + \lambda_{34}\, u_4 \geq \lambda_{21}$$
$$\lambda_{41}\, u_1 + \lambda_{42}\, u_2 + \lambda_{43}\, u_3 + \lambda_{44}\, u_4 \geq \lambda_{21}$$
$$-\beta_{11}E + \beta_{11}u_1 + \beta_{12}\, u_2 + \beta_{13}\, u_3 + \beta_{14}\, u_4 \leq 0$$
$$-\beta_{12}E + \beta_{21}u_1 + \beta_{22}\, u_2 + \beta_{23}\, u_3 + \beta_{24}\, u_4 \leq 0$$
$$-\beta_{13}E + \beta_{31}u_1 + \beta_{32}\, u_2 + \beta_{33}\, u_3 + \beta_{34}\, u_4 \leq 0$$
$$u_1, u_2, u_3, u_4 \geq 0$$

We can then solve the above DEA Linear Programming Model by utilizing **Management Scientist Software Package** to determine the values of the 5- decision variables, the reduced costs, the dual prices to determine the binding constraints and the slack/ surplus variables. Depending on the result we write the final report in the conclusion. We recommend consulting the help of the Management Scientist Software Package for reporting the results. Depending on the value of E as explained previously, we can judge on the relative performance of the department in question, H_1 relative to the composite department, H_c. We can repeat same steps for each department. We can also extend the analysis to include more inputs and more outputs in the DEA analysis.

This manuscript shows how to quantitatively evaluate the performance of a hospital in general rather than to evaluate a specific hospital as a case study. Hence, it would benefit researchers and practitioners in applying it on real case studies.

V. SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This manuscript presents main principles of optimal resource allocation in a hospital. It then presents the foundation of a quantitative method to evaluate the efficiency of a hospital. This is important to both scholars and practitioners to evaluate quantitatively the performance of a hospital from a pure economic perspective. Further manuscripts could consider other quantitative methods of hospitals' performance.

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