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Measurement of Capital in Cost Efficiency Analysis: Application to Dutch Hospitals

Master Thesis

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"Efficiency is difficult to measure, being, like wisdom, beauty and love, a quality about which there are inevitable definitional and quantitative challenges"

(Rowena Jacobs and Andrew Street)

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SUMMARY

This thesis examines the economic and statistical sensitivity to alternative instruments for capital input in the measurement of hospitals' cost efficiency. Efficiency is measured through a variable cost function. Capital is treated as the fixed input and measured in three alternative ways. The empirical analysis utilizes the longitudinal data on Dutch general hospitals. The three instruments for the quantity of capital are: the number of beds, the hospital's floor space and the estimated nominal undepreciated capital stock. The results show that the statistical properties of the cost function are in favor of the nominal undepreciated capital stock, mainly because of the significance of its coefficient. Moreover, its monetary nature constitutes the most precise depiction of capital stock. Estimated mean sector efficiency is very similar between the cost function utilizing the nominal undepreciated capital stock and the number of beds. Their close association is, however, contradicted by the inconsistent rank-order correlation. The floor space is assessed as the less reliable proxy especially due to its weak link to the hospital's total capital stock. These findings indicate relatively high sensitivity of the efficiency outcomes to the definition of capital. As a supplement to this analysis an alternative model is developed and presented in the thesis. This model addresses the issue of endogeneity of capital in Dutch hospital sector and thus better reflects the utilization of capital.

Keywords: capital, cost efficiency, cost function, nominal undepreciated capital stock, hospital

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PREFACE

This thesis analyzes different concepts of capital by utilizing empirical data. Readers should bear in mind that the concepts of capital as well as model specification are therefore based on the Dutch hospital sector and on the extent and quality of data which is at disposal. The hospital behavior determined by various regulations has an impact on defining the cost function and the capital input variables. The alternative method of the capital input construction is adjusted to the data availability and to Dutch financial and accountancy regulations.

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INTRODUCTION

The Dutch health care system has been recently characterized by increasing health care expenditures (see Chart A.1 in the appendix) and therefore efficiency in the health service provision is one of the important policy goals in order to maintain the public finance at sustainable level. Hospital care is the most visible component of health care spending (Folland et al., 2007) and since the limited market forces in the (Dutch) hospital sector might enable the health care providers to deviate from the economic efficient behavior, the policy makers use several instruments instead to motive hospitals to be efficient and to monitor their performance. Either productivity or cost efficiency assessment is the tool which controls hospitals' performance.

Frontier techniques[1] dominate in the measurement of relative efficiency in hospital industry. Various econometric and mathematical frontiers can be applied that basically explore the efficiency of a hospital relatively to its peers by measuring the use of resources to the production of the hospital. Various resources are used. Next to labor, capital is a primary input in the production of the hospital (Jacobs et al., 2006). A lot of attention has been paid to the output measurement while the input evaluation has been relatively neglected. The measurement of capital input, its quantity, cost and price is especially problematic and challenging (Folland & Hofler, 2001; OECD, 2001b; Coelli, 2003). Therefore the proper treatment and incorporation of capital into the efficiency analysis is very important (Coelli, 2005) and deserves further scrutiny. Researchers have been using several methods for construction of the capital input in the hospital efficiency analysis. These methods mainly depended on data availability but also on the chosen approach (for Data Envelopment Analysis see for example O'Neill et al., 2008; for Stochastic Frontier Analysis see for instance Rosko & Mutter, 2008; Besstremyannaya, 2010; for both methods read Worthington, 2004). This practice implies that the choice of an appropriate treatment of capital necessitates a careful consideration since the different constructions of a particular variable can affect the final outcome of the analysis.

The main purpose of this thesis is to examine the statistical and economic sensitivity in relation to the alternative capital definitions in the measurement of efficiency in the hospital sector. For this purpose an empirical analysis is conducted which utilizes longitudinal data on Dutch general hospitals. The modeling of an economic behavior utilizes a variable cost function (Kumbhakar & Lovell, 2003), where the data on quantity (for fixed inputs) and cost and prices (for variable inputs) are required. The capital was defined as the fixed input in order to detect the effect of its alternative definitions. Three distinct definitions of the quantity of capital are examined: number of beds, hospital's floor space in meters squared and estimated nominal undepreciated capital stock. The first mentioned instrument for capital quantity is widely used (for a literature review see Worthington (2004), for an utilization of this instrument see for instance Parking & Hollingsworth (1997) or Zuckerman et al. (1994)) because support services, equipment and administrative staff are related to the number of patients and the number of beds, respectively

[1] Probably most popularized frontier techniques are Stochastic Frontier Analysis and Data Envelopment Analysis (see for example Jacobs et al., 2006)

(Folland et all., 2007). The hospital's floor space is based on the same prerequisites though one can anticipate that the proportionality between the building's surface and the hospital's total capita stock fluctuates more among the hospitals (applied by e.g. Li & Rosenman (2000)). The last instrument for capital quantity is estimated from the annual depreciation cost. The nominal undepreciated capital stock is different from the previous proxies due to its monetary nature (the monetary proxies were used e. g. by Chirkos (1998) or by Valdmanis (1992)). This feature implies that the nominal undepreciated capital stock is more precise instrument for "consumed" capital and for available capital stock (Coelli, 2003). An assessment of the three instruments is based on statistical as well as economic properties. The statistical properties include the explanatory power of a cost function and the significance of its coefficients. The economic properties are judged with regard to the mean efficiency and a rank-order correlation between the specifications.

Aside from the measurement of the sensitivity to the three capital interpretation the thesis briefly addresses another phenomenon of the capital input, namely the endogeneity of capital. In the last chapter of the third section the alternative model is developed. This model distinguishes between the fixed and the variable assets. This division of capital stock respects the situation in the Dutch hospital sector, taking into account the time perspective and the regulation in the sector. The capital input quantity is measured by an approximation of nominal undepreciated capital stock and the cost of capital consists of depreciation cost plus opportunity cost derived from the long-term interest rate.

The structure of the thesis is divided into a theoretical and an empirical part. The theoretical part is further partitioned into two main sections. The first section covers principles of the efficiency measurement and the modeling. The second section comprises of the underlying theory of capital input and a review of the capital measurement in hospital efficiency studies. The empirical part develops the model for the efficiency measurement and defines its variables including the alternative capital instruments. This part is concluded by a description and discussion of results and followed by an additional chapter dedicated to the alternative model specification. All less relevant information, data and tables are in the appendix.

1 Theoretical framework for measurement of (cost) efficiency

This chapter aims to comprehensively describe the theoretical framework which stands behind the modeling applied in empirical part. Moreover, in order to put the modeling into context the chapter touches upon the relevant topics in the extensive efficiency measurement field. For in-depth discussion of alternative efficiency measurement techniques and models the reader is referred to Fried et al. (2008), Coelli (2005), Kumbhakar & Lovell (2003) or Jacobs et al. (2006).

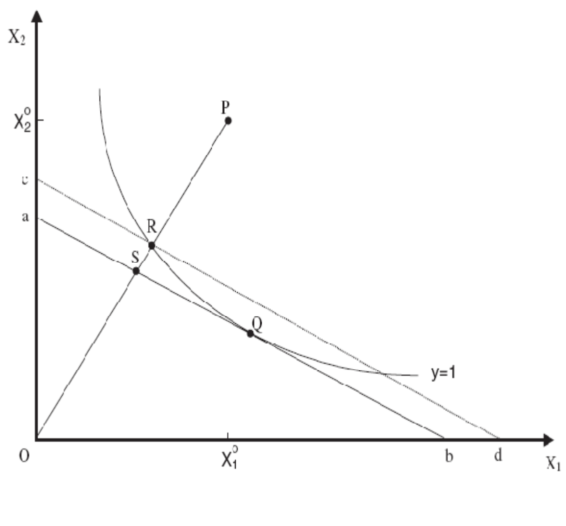
1.1 Definition of the economic efficiency

Economic efficiency (EE) has a technical and an allocative components and it was defined by Farrell (1957). The technical efficiency (TE) means that a firm produces the maximum attainable output given the technology and input. Its equivalent is that a firm uses as little input as required by the technology to produce given output. Allocative efficiency (AE) occurs when a firm produces an output mix which maximizes revenue, given the output price, or alternatively when a firm selects the mix of inputs which minimizes cost, given the input prices. Additionally, a technical change can occur if productivity is compared through time. Technical change captures advances in technology which shift the production function upwards and cost function downwards, respectively (Coelli et al., 1998).

The concept of technical and allocative efficiency can be clearly explained in Figure 1 (Hollingsworth, 2008). Figure 1 depicts a cost function (*y*) with a typical convex shape which symbolizes all combinations of two inputs (x_1 and x_2) which produce the same level of output. The two straight isocost lines *ab* and *cd*, respectively, characterize budget constraint. The producer labeled by letter *P* is not technically efficient because it uses more resources then the technology requires. By shifting producer from *P* to *R* we achieve technical efficiency. Nevertheless this producer, labeled by *R,* remains to be allocatively inefficient because it does not use that mix of resources x_1 and x_2 that minimizes cost. The producer will be economically efficient when the cost frontier is tangential to the lowest possible isoquant (this point is denoted by *Q*). Therefore

TE = 0R/0P and *AE = 0S/0R* and consequently *EE= TE x AE*, that is *0S/0P*.

Figure 1, Technical and allocative efficiency (Hollingsworth, 2008)



Economic behavior

Based on the economic behavior of the firm, organization or any decision maker unit, the economic theory identifies several models which reflect such a behavior. Production function characterizes producer whose goal is to maximize production; profit function identifies profit maximization behavior and cost function reflects the behavior of a producer who aims to minimize cost rather than maximize production or profit. The cost and its counterpart production function are fundamental building blocks for economic analysis of organizational efficiency (Jacobs, 2006).

The firms in the free market economy can be usually described by a production function with a concave shape. The cost function, which is ordinarily used to describe the behavior of hospitals has convex shape and indicates the minimum cost that an organization can incur in a production of a set of outputs. Inefficiency is defined as the excess of organization's cost to that predicted by cost function (Jacobs, 2006). Nevertheless Coelli (2003) expresses doubt about a cost-minimizing behavior in regulated firms. If the cost function does not reflect the cost minimizing behavior and firms systematically deviate from this behavior (e.g. due to imposed restriction by the government regarding rate of return), then the link between cost and production frontier is lost. The loss of duality results in incorrect measures of allocative, technical and scale efficiency and technical change.

1.2 Techniques for measurement of (relative) efficiency

Efficiency and performance are relative terms and therefore individual score must be viewed in context to other peers. A natural measure of performance is a productivity ratio that is an output/input ratio. Nonetheless this measure might be inappropriate when (1) multiple outputs are produced or (2) multiple inputs are used or (3) scale and scope effects are present (Ludwig, 2008). Therefore new techniques have been developed in order to avoid the mentioned shortcomings of productivity ratio. Moreover, these techniques are in line with the economic theory regarding economic behavior of the producer.

In theory, we distinguish between an econometric approach and a mathematical programming approach. The two approaches use different techniques to envelope data but neither approach strictly dominates the other (Fried 1993). Examples of the econometric approach are Stochastic Frontier Analysis (SFA) or Corrected Ordinary Least Squares (COLS), the mathematical programming modeling is represented by Data Envelopment Analysis (DEA)[2]. For more information about DEA see for example Ozcan (2008).

[2] DEA uses the frontier that joints the observations with the lowest ratio of cost to output and input prices. All observations that deviate from the frontier (upwards) are considered to be cost-inefficient. DEA is a deterministic approach and its frontier is solely defined by data. No assumptions are made about the functional form or the error distribution. On the other hand, in comparison to the econometric techniques, DEA generates the efficiency scores for the organization by comparing it only to peers that produce comparable mix of output. This fact results in (1) an assignment of a full efficiency to observation that lacks comparable peers and (2) assessing the performance of the organization taking into account only the peer organizations instead of a full sample (Jacobs et al., 2006).

The econometric approach to efficiency measurement can be categorized according to the data type (cross-sectional or panel data), the number of equations in the model (single or multiple equation model) and the type of variables they use (quantities only or quantities and prices) (Fried 1993). The subsequent chapters are dedicated to the econometric approach with multiple equations that utilizes panel data because this methodology is used in the empirical part of the thesis.

The multiple equation panel data model for cost function

This model was popularized by Christensen and Greene (1976) and used for instance by Blank & Merkies (2004). The model utilizes panel data where each producer is observed over a period of time. The model is characterized by the system of equations and describes the behavior of the cost-minimizing producer.

$$\ln (w^T x)_i = c\,(\ln y_i, \ln w_i; \beta) + v_i \qquad (Eq.1.1)$$

$$w_n x_n / (w^T x)_i = s_n\,(\ln y_i, \ln w_i; \beta) + v_{ni} \qquad (Eq.1.2)$$

$(w^T x)_i$ denotes total cost of *i*-th producer
y_i = output (production) of *i*-th producer
w_i = input price for the *i*-th producer
$w_n x_n$ = cost of *n*-th input $n = 1, 2, 3, \ldots, m.$; m = number of inputs
β = parameter(s) to be estimated
s_n denotes Shephard's lemma
v_i and v_{ni} capture the effect of statistical noise

The first equation *(Eq. 1.1)* is cost function and the remaining *m*-equations *(Eq. 1.2)* are derived from it by applying Shephard's lemma (1953) [3] in order to generate cost-minimizing input cost shares. The purpose of inclusion of cost-share equations was to increase statistical efficiency when running the regression since parameters appearing in input equations are contained also in the cost function. The commonly used functional form for the equations described above is translog functional form (Fried, 1993) which is described in subsequent chapter. When measuring the economic efficiency we relax the assumption of cost minimization driven by Shephard's lemma and with respect to the deterministic model (which implies dropping statistical noise v) we transform the equations *1.1* and 1.*2* as follows:

$$\ln (w^T x)_i = c\,(\ln y_i, \ln w_{i,}; \beta) + T_i + A_i \qquad (Eq.1.3)$$

$$w_n x_n / (w^T x)_i = s_n\,(\ln y_i, \ln w_i; \beta) + u_{ni} \qquad (Eq.1.4)$$

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[3] Shephard's lemma says that every cost function has a unique cost minimizing point for given inputs and their prices. In other words Shephard's lemma finds the unique mix of input quantities (with respect to their prices) which minimizes cost. The *n*-th input cost minimizing quantity (= cost share equation S_n) is given by derivation of cost function *C* with respect to the price of the *n*-th input w_n:

$$S_n = \frac{\partial C}{w_n}$$

u_{ni} constitutes the departure of an observed cost share equations from their cost-minimizing magnitudes and is therefore associated with allocative inefficiency *(A_i).* Technical inefficiency is denoted by T_i . The technical inefficiency has no impact on input share equations while allocative inefficiency must be linked to the input cost share equations (Fried, 1993) because these equations determine the cost-minimizing input mix.

Translog cost function

To define the relationship of cost to outputs and input prices a functional form of the model must be specified. The Cobb-Douglass and translog models overwhelmingly dominate in literature on the economic efficiency estimation (Fried 2008). The translog model is derived from Cobb-Douglass. Both models have advantages and disadvantages[4] but translog seems to be preferred (see for instance Rosko & Mutter, 2008 or Coelli, 2003). The translog cost function is specified by *(Eq.1.5)*.

$$ln(C) = a_0 + \sum_{i=1}^{m} b_i \ln(Y_i) + \sum_{i=1}^{n} c_i \ln(W_i) + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} b_{ij} \ln(Y_i)(Y_j) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\, ln(W_i)(W_j) + \sum_{i=1}^{n}\sum_{j=1}^{m} d_{ij}\, ln(W_i)(Y_j) \qquad (Eq.1.5)$$

C= total cost

Y_i= i-th output (i=1, 2, 3,…,m)

W_i= i-th input price (i=1, 2, 3,…,n)

b_i, b_{ij}, c_i, c_{ij}, d_{ij} are parameters to be estimated

Homogeneity restrictions are imposed on the cost function. The function is homogenous of degree one in input prices. This restriction ensures that the same change in all input prices will result in the proportionally same change in costs (Coelli, 2003). The restriction imposed on the cost function in *(Eq. 1.5)* can be described by *(Eq. 1.6).*

$$\sum_{i=1}^{n} c_i = 1, \sum_{i=1}^{n} c_{ij} = 0, \sum_{i=1}^{n} d_{ij} = 0 \qquad (Eq.1.6)$$

1.3 Modeling of residual

When using the econometric approach, the cost inefficiency is approximated by the deviation from the cost frontier (in econometrics this is symbolized by the error term). There are two basic concepts of modeling this error term. The stochastic approach distinguishes the effects of statistical noise from the effects of inefficiency (e.g. SFA). On the contrary, the deterministic approach confounds both effects into inefficiency (e.g. COLS).The difference of the two ways of

[4] The Cobb-Douglas is a simplification of translog function and is more parsimonious. Translog function is, however, more flexible and reflects the lognormal distribution of hospital costs (Ludwig, 2008).

treatment of error component can be illustrated on (*Eq. 1.8)*. The cost function of *i*-th organization is characterized by

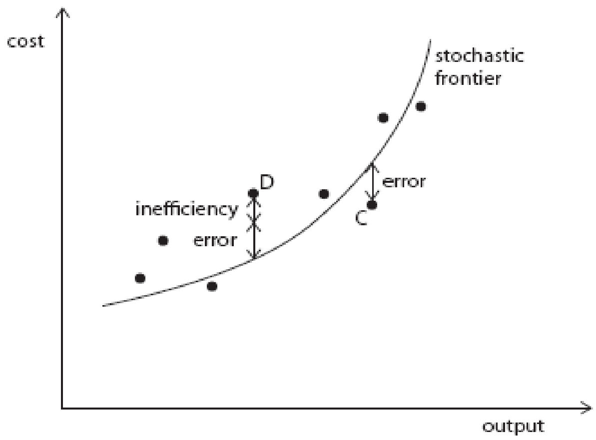
$$\ln (w^T x)_i = c(\ln y_i, \ln w_i; \beta) + \varepsilon_i, \qquad (Eq.\ 1.7)$$

where, ε_i is a residual from observed cost to the estimated cost defined by the frontier. The residual can be then divided into v_i and u_i so that

$$\ln (w^T x)_I = c(\ln y_i, \ln w_i; \beta) + v_i + u_i \qquad (Eq.\ 1.8)$$

where, v_i captures stochastic events not under the control of the organization . It can be statistical noise, errors in measurement or exogenous shocks (Rosko &Mutter, 2008). u_i denotes inefficiency. The key assumption underlying the stochastic approach is that v_i and u_i will be distributed differently. The v_i is assumed to be normally distributed while u_i must be nonnegative (usually assumed to have half-normal, exponential or gamma distribution (Street, 2003)). If ε_i follows normal distribution all residuals are interpreted as statistical noise. if ε_i is skewed, the inefficiency is present (Jacobs, 2006). The assumption of the inefficiency error distribution leads to different efficiency scores (Street 2003) but can be relaxed if panel data is available (Kumbhakar & Lovell, 2003). The stochastic cost function can be estimated for instance by Ordinary Least Squares (OLS), by maximum likelihood or by modified OLS (Fried et al., 1993).

Figure 1: Stochastic frontier

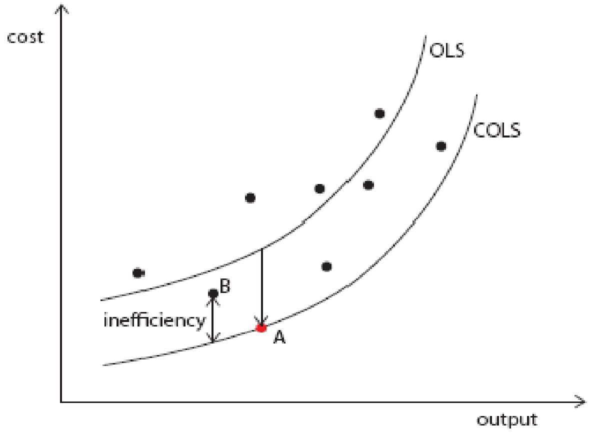


The deterministic approach suggested by Aigner & Chu (1968) consider v_i to be zero and $u_i \geq 0$ and therefore the entire error term is attributed to inefficiency ($\varepsilon_i = u_i$). The cost function can be estimated by OLS. The estimated cost function is then shifted downward by adding the minimum (negative) residual to the estimated intercept and thus the frontier bounds the previous data (Rosko & Mutter, 2008). This is formally expressed in (*Eq. 1.9).* The relation between the error term in OLS and COLS is described by (*Eq. 1.10).* The idea of COLS is illustrated in Figure 2. Point *A* depicts the minimum residual.

$$\beta_{0,\,COLS} = \beta_{0,\,OLS} - \min_i u_{i,\,OLS} \qquad (Eq.\ 1.9)$$

$$u_{i,\,COLS} = u_{i,\,OLS} - \min_i u_{i,\,OLS} \qquad (Eq.\ 1.10)$$

Figure 2: Corrected Ordinary Least Squares frontier



The COLS model faces several drawbacks. Firstly, this model is deterministic which means that any deviation of observed values from their predicted values is attributed to inefficiency (no effects of statistical noise are captured). Secondly, the producer that has largest negative OLS residual indicates “best-practice” observation and supports the COLS cost frontier. This makes COLS vulnerable to outliers. Thirdly, the structure of the COLS is identical to the OLS apart from the shifted intercept and thus the model assumes that the best practice is just like an average practice given by the OLS frontier (Fried et al., 2008). On the other hand, COLS relaxes the assumption made for the error distribution and might be viewed as more convenient for the analysis with multiple equations. This feasibility was the main motive for using COLS in the empirical part of this thesis.

2 Capital as an input

Capital is an important input in production. This holds also for hospital production. However "incorporating measures of capital into the efficiency analysis is challenging" (Jacobs et al., 2006) due to (1)difficulty of measuring capital stock and (2)problems in attributing use of capital for a certain period (Jacobs et al.,2006). The former difficulty is not concerned only with measuring capital quantity but also its cost and prices "Measuring the quantity, price, and cost of capital is challenging" (Coelli et al., 2003). The second challenge is associated with capital deployment across time. For instance current production relies on capital investment from previous years and vice versa actual investments may provide endowment for future production. The endowment is either in form of real capital (medical equipment, buildings) or in health capital (health promotion and prevention programs). Due to measurement pitfalls with the second form of capital the non-physical capital inputs are usually neglected.

With regard to treatment of capital across time another important issue arises, namely time perspective. In the short-run the amount of capital is more or less given and the task of the hospital is to optimize utilization of such "fixed" asset. While in long run we expect that the hospital is in the position to reconfigure its capital resources in order to pursue (allocative) efficiency improvements (Jacobs et al., 2006). For instance in a less regulated hospital market (e.g. in the USA) one can assume the hospital building to be a fixed asset in perspective of one year (in case of cross-sectional data). But if we observe the hospital production during several years then the management is expected to adjust also the fixed assets capacity (like buildings) to the hospital production. In the long run all inputs are variable inputs (Coelli et al., 2002). Because of the cost function the subsequent sections deal not only with capital quantity but also with capital cost and capital price measurement issues. Additionally, in order to clarify sometimes confusing terminology and concepts the following sections lay down the main notions. The sections 2.1 and 2.2 draw heavily from Coelli et al. (2003) and OECD (2001a and 2001b).

2.1 Quantity of capital services

The quantity of capital input in production should reflect the service flow of capital stock. Capital stock is cumulative stock of past investments and can be partitioned into various assets like buildings, computers or medical inventory. This service flow is seen as an actual input in a production process. For example, the quantity of human capital in production is not the number of personnel employed, but the total person hours worked. Similarly, quantity of capital is not the number of machinery in the production process but services drawn from the machinery, usually measured in total machine hours. The quantity of capital services is usually not directly observable, for instance service flow of the hospital building which provides comfort and protection against bad weather. Therefore service flow is approximated by assuming that it is in (fixed) proportion to capital stock (OECD, 2001a).

The service flow can be constant over the asset's life or can decrease. The volume of service flow can be therefore independent of the age of the asset or can fall during the asset lifetime. In the former case accountants developed linear (straight-line) depreciation where the purchase cost of the asset is equally distributed in the asset's life. In the straight line depreciation model "the depreciation for an asset which is t years old is set equal to a constant fraction of the value of a new asset P_0 over the life of the asset "(Lau, 2000).

$$D_t=(\frac{1}{N})P_0 \qquad (Eq.2.1)$$

where, N is the useful life of a new asset and t = 0,1,2, …, N-1.

If the service flow of a particular asset changes over time, different depreciation methods are possible. These methods depend on an age-service flow pattern. Therefore accountants developed a proxy of the volume of service flow during the life asset and therefore they are attributable to particular period of time.

Nevertheless accountancy techniques of capital consumption face several pitfalls: (1) it does not consider inflation and (2) different firms may use different accountancy approaches (different depreciation patterns or asset lives) (OECD, 2001a). Coelli (2003) adds (3) different interpretation of depreciation in accountancy and economics[5] and (4) different tax rules and inflation rates in international comparison data. Jacobs et al., (2006) stated that "Accounting methods usually represent meaningless indication of capital consumption ".

Nevertheless three out of four problems can be overcome when all historical investments are at hand. In this case we could deflate investments to constant prices and apply the same depreciation rules for all firms. This is can be done by Perpetual Inventory Method (OECD, 2001a). PIM refers to single type of the asset (assumption of homogenous capital). A further assumption is made about proportionality of capital services to productive stock[6].

$$K_{i,t}^{P} = \sum_{\tau=0}^{T} h_{i,\tau}.F_{i,\tau}\frac{IN_{i,t-\tau}}{q_{i,t-\tau,0}} \qquad (Eq.2.2)$$

$IN_{i,t}$ = nominal investment expenditure on asset type *i* at time *t*
q = price index of the asset *i*
$F_{i,\tau}$ = is a retirement function (indicate the share of assets of age τ that are still in service)
$h_{i,\tau}$ = an age-efficiency profile (specific the loss in productive efficiency as the asset ages)
T = the maximum service life

[5] In accounting, the depreciation is used to attribute historical cost of an asset across its useful life. It does not have to reflect wear and tear, the obsolescence or change in demand for the services of that asset. Economic concept deems depreciation as a decrease in the economic value and therefore considers physical depreciation, obsolescence and changes in the asset's market value (Kim & Moore, 1998).

[6] The flow of capital services is more difficult to measure. Typically it is assumed that productive service of an asset is the proportion of the capital stock of such an asset (Coelli, 2005). However proportionality between capital stock and its service flow might not be realistic due to different levels of utilization over the time. The assumption of constant level of utilization over time is one of the reasons of pro-cyclical behavior of productivity series (OECD, 2001b) (e.g. during the economic downturn and diminished demand the utilization capacity usually decreases but this is not captured due to the assumption of the constant utilization rate).

In reality researchers are constrained by data availability. In case of missing capital investment history alternative methods should be used for computation of the volume of capital. The methods proposed by Coelli et al. (2003) are listed below:

- Monetary proxies
  - Depreciated and undepreciated replacement value- the value of the capital stock is determined by the cost of replacing it. The undepreciated replacement value should be in theory equal to the initial deflated price of the asset. The effect of inflation is removed for both methods. The estimating of the replacement value is costly and time-consuming.
  - Sale price-if the firm is sold at the market for a certain price then the value of capital stock should be reflected by the sale price.
  - Nominal depreciated and nominal undepreciated capital stock- the value is routinely reported in entity's annual accounts. The computed value will be biased due to inflation and lumpy investment.
- Physical proxies

  The choice of proxies depends on the particular industry. Classification of capital assets should be followed by finding a suitable proxy (for instance building=>meters squared, computers=>number of desktop computers). There are, however, significant problems associated with physical measures: they do not capture the quality of individual items and usually assume homogeneity of capital (ICU vs. long-term beds). Coelli et al. (2005) suggests examining a sensitivity of productivity scores to the choice of different physical proxies. On the contrary, aggregation of capital items together form a single capital variable and minimizes the number of variables, thus conserving degrees of freedom.

2.2 Cost and prices of capital services

Proper monetary assessment of productive capital stock is an important presumption in the cost function. Recently, there has been considerable consensus for cost and prices measurement in efficiency studies (Rosko & Mutter, 2008). The trend of converging definition of cost and prices is also supported by the overview of efficiency papers wrote by Worthington (2004).

The capital cost usually comprises depreciation and interest expenses. Interest expenses are actually cost of debt which the capital is financed from. However, this measurement may not be fully consistent with economic theory because it does not include opportunity cost. Since the entire model is based on economic theory, it is necessary that also capital is judged from this viewpoint. Moreover, the proper treatment of cost during the time requires discounting and considering the change of market value for a specific asset.

Conceptually correct valuation of capital cost was formulated by Jorgenson (1963). Capital cost can be defined as user cost or rental price of capital. The user cost implicitly expresses the price of capital services to its owner. Utilization of user cost is more plausible because market prices are usually not available. The formula for computing user cost is situated below.

$$\mu_t = q_t \, . \, (r_t + d_t) - (q_t - q_{t-1}) \qquad (Eq.\ 2.3)$$

μ_t = the cost of using the service of capital good for a given period (e.g. one calendar year)
q_t = market price of a new asset
d_t = depreciation rate
r_t = cost of financial capital

r_t is interest payment if loan was taken to acquire the capital good or opportunity cost. Depreciation rate reflects efficiency loss or physical decay of the asset. $(q_t - q_{t-1})$ corresponds to the change of market price of the new asset and is independent of the effects of ageing (e.g. the fall in price due to obsolescence). Possible pitfall is the formula's abstraction from all effects of taxation like corporate income taxes or tax depreciation allowances (Lau, 2000).

The price of capital input is not usually available and must be implicitly defined. Based on fundamental asset market equilibrium condition formulated by Hill (1999) the price of an asset should be equal to the discounted stream of its future services. In notion of productive efficiency, we are interested in this service flow per given time (usually one calendar year) which is the actual input. OECD (2001b) suggests to measure price of capital services by their rental price. Nevertheless, since the rental price is usually not directly obtainable, the price can be derived from user cost by a simple equation defining cost as a function of quantity and price. If (user) cost = quantity × price then derived price = cost/quantity. The question is whether firms (hospitals) face individual (different) or the same capital price. If it is believed that the prices are exogenous (=one price for the capital on the market), industry-level price data should be used (instead of firm-level prices implicitly deduced by dividing firm-level cost by firm-level capital quantity) (OECD, 2001b). Price of capital is usually treated as exogenous (Rosko & Mutter, 2008). However Zuckerman et al. (1994) viewed capital as an endogenous variable since hospital management has the power to choose the mix of capital equipment. By applying cost-minimizing behavior it is assumed that hospitals are price takers and therefore we should avoid endogeneity. Based on the situation in the Dutch hospital market, Blank & Eggink (2004) treat capital as exogenous input.

2.3 Measuring of capital input in hospital efficiency analysis: Literature review

This chapter reviews and describes different approaches to capital measurement in cost effectiveness analysis in the hospital sector. Next to the standard capital measurement the focus is also centered on analysis which dealt with the capital quantity, cost or price in a unique way. The different concepts of capital are ordered with respect to the author and the particular study. Due to the nature of the cost function, capital measurement heavily relies on its prices and cost. Nonetheless in the variable cost function used in our empirical analysis and specified by

Kumbhakar & Lovell (2003), capital quantity might be one of the (fixed) inputs. Additionally, capital quantity can implicitly determine the price or cost if one of those two is not available. Short author's comments to different practices are made if necessary.

Capital input quantity

Perhaps the simplest though frequently used method of capital quantity measurement (used e.g. by ***Wagstaff (1989)*** or ***Parking & Hollingsworth (1997)***) proxies the capital quantity of the hospital by the number of staffed beds without further interest in capital price or cost[7]. This method is used on assumption that hospital capital stock is in fixed proportion to the number of beds. As Folland et all. (2007) noticed, hospital size is usually measured by number of beds, because support services, types of equipment and administrative staff are related to the number of patients that the hospital can house, and hence the number of beds.

In literature written by ***Blank & Merkies (2004), Blank & Eggink (2004)*** or ***Blank & Vogelaar (2004)*** capital quantity is approximated by an index consisting of the number of beds, number of surgery rooms, number of x-ray rooms, and number of delivery rooms. The detailed explanation of capital index is given by ***Blank et al. (2000).*** Capital is divided into two categories: buildings and medical inventory. Separate regression formulas were constructed where initial capital expenses (interest expenses+ depreciation) deemed as dependent variables were related to the volume and quality indicators and to the age of the capital. Volume proxies consisted of the number of beds, number of surgery rooms, number of x-ray rooms and number of delivery rooms for both categories. The presence of a first aid department, CT-scanner and radio therapy department indicated the quality of the buildings while the quality of medical inventory was given by availability of a first aid department and CT-scanner only. After analyzing the models the capital quantity did not incorporate the age and capital quality. Buildings and medical inventories were finally aggregated into one single volume index by cost share weighting. Buildings' and medical inventory's mean cost shares were 0.8 and 0.2, respectively.

Ozcan (2008) dealt in his book with capital as an input in DEA. He distinguishes two types of capital proxies: (1) plant size, measured by number of staffed beds and (2) plant complexity, a proxy considering the availability and extent of diagnostic and special services. Construction of the plant complexity instrument is dependent on data availability and on service division and its number. Its rationale is quite simple. If the hospital provides a particular service (that means the investment is available) then this service can be coded as 1, and vice versa, if the investment is not in place we code this item as 0. The two proxies were tested in terms of their approximation of actual asset by using empirical data. It was found that the two instruments are significantly associated to capital asset and therefore they can be regarded as appropriate proxies for capital stock.

[7] This approach is common for DEA. The prices and cost of capital can be ignored also in a cost function where capital is exogenous to hospital management.

Capital input cost, price and quantity

Zuckerman et al. (1994) defined cost of capital as the sum of interest expenditures and depreciation. The price of capital was inferred from the cost by dividing it with the number of beds. This computation implicitly regards the number of beds as the quantity of capital. The price of capital can be defined as

$$w_i = \frac{i_i + d_i}{beds_i} \qquad \text{(Eq. 2.4)}$$

i indicates hospital
i_i = total interest payments
d_i = depreciation charges

The individual prices for each hospital suggest capital endogeneity. This method is a dominant measure of the cost of capital (see for example review of cost function variables used in US hospital SFA studies written by Rosko & Mutter (2008). The same authors qualify the method as "a consensus definition for the price of capital in national (US) studies".

Li & Rosenman (2000) measured the price of capital as ∑(depreciation+leases+rentals)/ square footage of the hospital and thus regarded the hospital floor space as the capital quantity. In addition, the number of beds for each hospital was included in the cost function as an independent variable in order to control for the current state of capital. This number of beds was considered as a proxy for "hospital size and capital endowment". According to the author the price of formula gives us "information about a long run cost function".

Depreciation charges for plant (building and land) and depreciation charges for movable and fixed equipment plus interest expenses were used as a cost of capital by ***Chirkos (1998)***. Prices were derived by (1) dividing a sum of depreciation by a book value of plant and equipment and by (2) dividing interest expenses by the value of current assets.

Valdmanis (1992) has used net plant asset in order to provide the nominal value of capital that the hospital uses. Then he compared the efficiency outcomes by using the net plant asset and the number of beds in DEA analysis. He focused on the difference in technical efficiency among public and not-for profit hospital. The difference was statistically significant when he used beds as the capital. On the contrary, no statistical difference in technical efficiency between public and not-for profit hospital existed when the net plant asset was used. The author suggested this might have been caused by wider variation in net plant asset among hospitals.

Folland & Hoffler (2001) pointed out that classical capital cost defined as depreciation and (paid) interest to the staffed bed neglects equity. They developed a sophisticated and conceptually correct method which deserves a detailed description and evaluation. Its formula is shown below. It is apparent that this method necessitates extensive or specific data availability.

$$w_i = P_i(i_i + \delta - \rho_i),$$

where $i_i = \partial_i d + (1 - \partial_i)e.$

P_i = prices or costs of constructing a bed locally (local value of cost index is applied)
i_i = interest rate, calculated as the weighted average (∂) of the interest rate for debt (d) and the rate of return on equity (e)
δ = depreciation rate (is assumed to be common for all hospitals. Assets life is assumed to be 30 years and straight line depreciation is applied which implies δ=0.0333)
ρ_i = inflation rate

The formula employed by Folland &Hoffler (2001) allows equity rates and debt rates to differ and takes the inflation into account. Moreover, P_i plays "a weighty role" and determines over or under use of an input relative to capital. The authors compared the sensitivity of the efficiency estimates to the standard and their innovative capital cost construction. Both equations performed well and yielded similar coefficients for most variables including the cost of capital measures (Folland & Hoffler, 2001). The equation with an innovative approach incurred 3.5 % higher mean capital cost and raised mean inefficiency from 14.4% to 16.1%. The mean inefficiency estimates for the two models had Pearson correlation coefficient of 0.75. The same data set was employed for both equations (n=791). The authors concluded that the theory and limited sensitivity to accountancy practices are in favor of an alternative formula. By contrast data requirement (which may result in drop of sample size) and intermediate data steps are considerable drawbacks.

The PhD thesis investigating the efficiency o Dutch hospitals presented by ***Ludwig (2008)*** excludes cost and price (and implicitly quantity) of capital. The reasoning of the exclusion was that the hospital management has little influence on the volume and on cost of capital because capital investments in buildings are regulated by the Dutch government. Nevertheless the concept of capital is not accurate in the study. The author defined buildings as only capital of hospital. The costs of patient related machines and inventory are deemed as material costs. Their costs are approximated by the depreciation value. The prices are adjusted by price indexes. The costs (and prices) of buildings are left out the analysis and according to the author they account on average for 12% of the total cost.

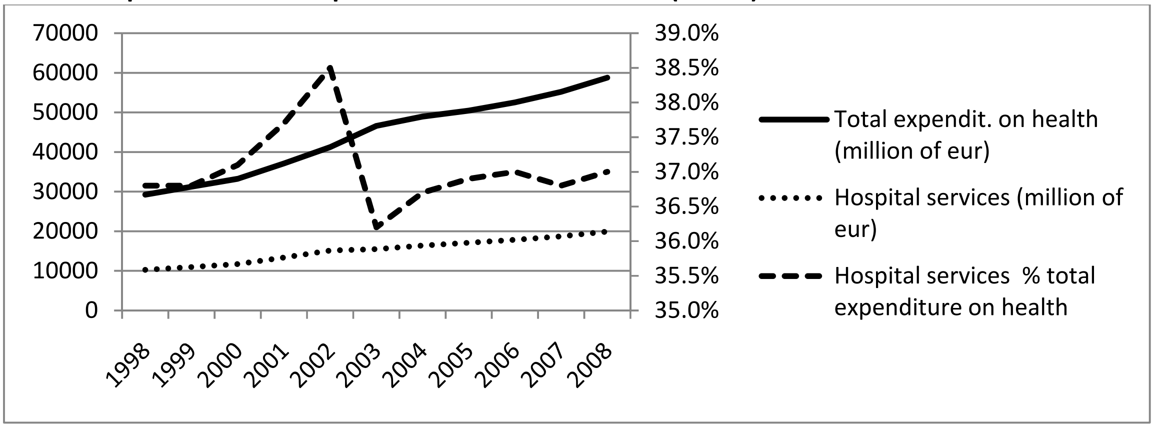
3 Assessment of alternative capital interpretations: Application to Dutch hospitals

This section utilizes panel data on Dutch general hospitals in order to analyze the alternative definitions of capital input. The section is introduced by a chapter describing the Dutch hospital sector. It is followed by the definition of a general model which is used for the analysis. The next chapter deals with the construction of its variables. In total three definitions of capital were laid down. The capital was treated uniformly as fixed input in order to compare its effect across models. The section is concluded by results of statistical and economic sensitivity to the various capital interpretations. Assuming that capital is fixed input and is therefore exogenous to hospital management might not hold in the Dutch hospital sector. The endogenity of some capital assets generates modification to general model. This issue is addressed in additional chapter 3.5* which develops and presents the alternative model.

3.1 Dutch hospitals

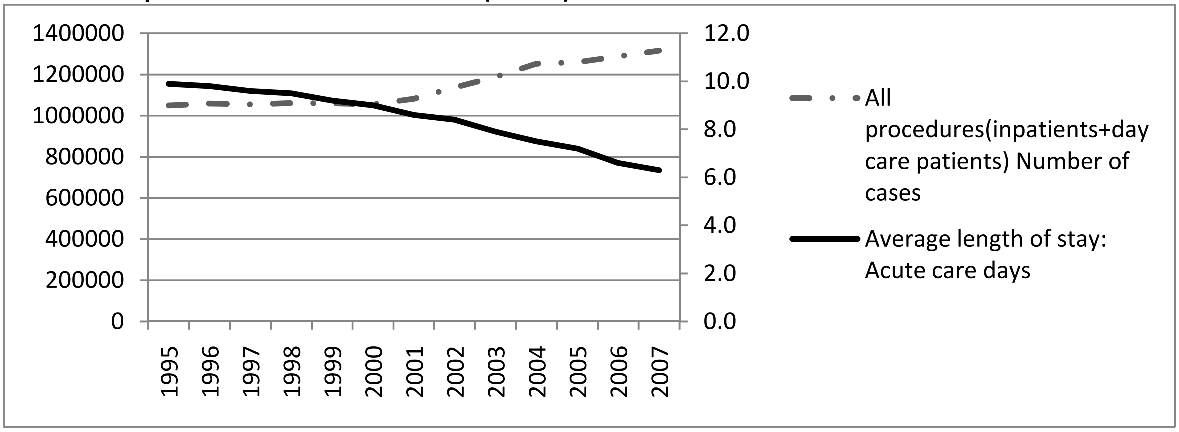
The cost of hospitals represents the major health care spending. In the Netherlands 37% of the total spending on health care was devoted to hospital services (OECD Health Data, 2009). The evolution of expenditure in current prices is depicted in Chart 1. One can observe a steady increase in the total hospital cost and the total expenditure on health. The latter is growing at faster pace. The remarkable fall in hospital cost as a percentage of total health care spending in 2003 is due to a sudden increase in the total expenditure while hospital cost increase was insignificant (OECD Health Data, 2009).

Chart 1: Expenditure on Hospital Services. Source: OECD (2010a)



In addition to the increasing health spending, the changes in health care utilization represent another phenomenon in the development of current health care. Given the increasing unit hospital cost, the hospitals tend to rationalize the provision of health care services and thus contain the costs. The cost containment is characterized by the shift from inpatient procedures to outpatient procedures. Chart 2 depicts a total number of surgical procedures for both inpatients and outpatients which has been rising over time while an average length of stay has been steadily decreasing (OECD 2009). This reduction has coincided with a diminishing number of hospital beds per capita and an increasing number of ambulatory surgical procedures (OECD Health Data 2010).

Chart 2: Hospital Services. Source: OECD (2010a)



All hospitals in the Netherlands are non-profit organizations and the most of them are specified as foundations. They can make a profit, but this profit is subjected to reinvestment in health care and cannot be distributed to shareholders. The remuneration for a physician is based on fee-for-service payments. Patients need a referral from their GP to be treated in a hospital. Hospitals are obliged to treat all referred patients if they have available capacity (Meijer et al., 2010).

The major purchaser of hospital services are health insurers. The prices for services might be either fixed or negotiable while volume and quality are always negotiable. The free prices were introduced in 2005 aiming to enhance competition among health care providers. In terms of inpatient care, 66% of care (situated in so called segment A) has fixed prices for treatments. The remaining 34% of treatments (situated in segment B) is characterized by negotiable prices. Prices are the main discussion point during negotiation between hospitals and insurers and most hospitals differentiate prices among insurers. The insurers also attempt to restrain the volume of services by setting the maximum level of volume growth rate. The quality is also discussed during the negotiations however insurers' quality measurements motivate only some providers to improve their services. One explanation of this behavior might be the fact that every insurer applies its own specific quality measurement methods. In 2009, none of the Dutch hospitals was vertically integrated with health insures (Meijer et al., 2010).

Competition among hospitals plays also an important role and has an impact on the level of prices, quality and volume. One of the common strategies to remain competitive is to apply a new medical technology or a specialization on certain treatments. The tendency of narrowing hospital focus and thus differentiate from other health care providers is likewise observable among general hospitals. Other differentiation strategies are oriented on reputation and marketing, cooperation with other hospitals, price, quality and price-quality aspects (Meijer et al., 2010).

Since our data set is from 1995 to 2002 it is appropriate to point out the different aspects of hospital market during the observed time. From 1995 to 2002 the general hospitals were fully reimbursed by central government. Reimbursement was based on a variable component related to production capacity (number of beds, number of adherent patients, and number of associated physicians) and a variable component related to production (number of patient visits, patient days and discharges). All prices for medical treatments and procedures were fixed (Blank & Merkies, 2004). These aspects suggest more limited competition from 1995 to 2002 than in the present hospital market.

Economic behavior of Dutch hospitals

We assume cost minimizing behavior of Dutch hospitals. This assumption is derived from the fact that part of the hospital budget is determined by authorities in advance and the hospital cannot influence the level of production or in other words the number of treated patients, because hospitals cannot refuse incoming patients. By contrast we assume that hospitals are free to choose the quantity and the mix of input[8]. Nevertheless Blank and Merkies (2004) studied the economic behavior of Dutch hospitals and proved that in the long run the hospital production can be endogenous to the hospital by selecting patients through specialization of hospitals which coincides with the actual trend in the sector described above. Therefore they suggested a modified cost model. Given the limitation of this thesis the analysis ignores their suggestion.

3.2 Model specification

The model specification used for this paper is inspired and based on modeling used by Blank & Vogelaar (2004), Blank & Eggier (2004) or Blank & Merkies (2004). Given the economic situation in regulated Dutch hospital industry where some inputs might be considered as fixed inputs (like capital), the variable cost function seems to be most appropriate. If some inputs are fixed it is not possible for an organization to minimize total cost but just to minimize cost related to variable inputs, namely variable cost. Kumbhakar &Lovell (2003) define the variable cost *frontier*[9] as

$$vc\,(y, w, z) = min_x\{(w^T x : (y, x, z) \in GR\}, \qquad (Eq.\ 3.1)$$

where variable input vector (x) at price (w) and fixed input (z) are used by the organization to produce output (y). Frontier is defined by the hospital(s) with minimum cost $w^T x$ given the volume of production, fixed and variable inputs. The cost function must be a (1) nonnegative function, (2) homogenous of degree one in input prices and must be (3) monotonic non-decreasing in input prices and (4) concave in input prices (Blank & Eggier, 2004) and additionally (5) monotonic nondecreasing in y and nonincreasing in z and concave in z and y (Kumbhakar &Lovell p.41, 2003). After application of the translog functional form the model which depicts the cost frontier in time *t* is described by the following equation:

[8] There exist, however, a constraint for the major capital investments. This limitation results in division of capital into fixed and variable components and will be further discussed in Chapter 3.3.

[9] The frontier in COLS depicts 100% efficiency, its allocative and technical inefficiency are therefore equal to zero as well as the error term is zero.

$$\begin{aligned} min \ln(VC)_t = \; & a_0 + \sum_{i=1}^{m} b_i \ln(Y_{it}) \; + \sum_{i=1}^{n} c_i \ln(W_{it}) + \sum_{i=1}^{o} d_i \ln(Z_{it}) + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} b_{ij} \ln(Y_{it})(Y_{jt}) \\ & + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\, ln(W_{it})(W_{jt}) \; \frac{1}{2}\sum_{i=1}^{o}\sum_{j=1}^{o} d_{ij}\, ln(Z_{it})(Z_{jt}) + \sum_{i=1}^{m}\sum_{j=1}^{n} e_{ij} \ln(Y_{it})(W_{jt}) \\ & + \sum_{i=1}^{o}\sum_{j=1}^{n} f_{ij} \ln(Z_{it})(W_{jt}) + \sum_{i=1}^{o}\sum_{j=1}^{m} g_{ij} \ln(Z_{it})(Y_{jt}) + \sum_{i=1}^{p} a_i\, T_i \end{aligned}$$

(Eq. 3.2)

where *t* is a subscript for time, m is the number of outputs, n is the number of variable inputs and *o* denotes the number of fixed inputs. The T_i is a year dummy and captures technological change[10]. Homogeneity of degree one in input prices is exerted. By applying Shephard's lemma to variable cost function we get input shares equations. The number of share equations depends on the number of corresponding *variable* inputs. The input cost share equation is specified as:

$$S_{it} = c_i + \sum_{j=1}^{n} c_{ij} \ln(W_{jt}) \; + \sum_{j=1}^{m} e_{ij} \ln(Y_{jt} + \sum_{j=1}^{o} f_{ij} \ln(Z_{jt}) \qquad (Eq. 3.3)$$

The system of equation which consists of variable cost function and n input cost share equation is then regressed against variable cost. In this multi-equation system the errors are likely to be cross-equation correlated (Blank & Vogelaar, 2004) and therefore Seemingly unrelated regression (SUR) method (Zellner, 1962) is used for the estimation of parameters[11]. This means that cost function and n-1 cost share equations[12] are simultaneously regressed with series of iterations. This regression as well as the majority of computation is run by the statistical program TSP.

The economic efficiency is computed by application of the COLS method where the residuals for each hospital are averaged over the years and standardized at the maximum residual (Blank & Vogelaar, 2004; Kumbhakar & Lovell, 2003). The estimated cost function is shifted downward by adding the minimum (negative) residual to the estimated intercept and any deviation from this frontier with minimal (variable) cost is attributed to economic inefficiency. Therefore there will be

[10] The specification of the time variable diverges from a proposed specification by Coelli et al. (2005). The authors suggest including also the squared time variable and its cross terms with produced services and resource prices. The incorporation of squared time provides conceptually better time specification. The parsimonious treatment of time should not cause, however, a dramatic change in both statistical and economic properties of the model (see for instance Blank & Vogelaar (2004), where statistical and economic sensitivity of the model to different treatment of time is more or less negligible).

[11] The equation and their variables bear close conceptual relationship to each other which results in correlation of error terms. The SUR method involves generalized least square procedure and achieves an improvement in efficiency by taking into account the presence of the cross-equation error correlation (Pyndick & Rubinfeld, 1998).

[12] One input share equation is eliminated from the regression in order to avoid singularity of the variance-covariance matrix of the error terms (Blank & Vogelaar, 2004).

only one hospital 100% efficient and other hospitals will report inefficiency. The average economic efficiency of i-th hospital (EE_i) over the years is then computed as

$$EE_i = \frac{\frac{1}{N_i}\sum_t u_{it}}{max_k\left(\frac{1}{N_k}\right)\sum_t u_{it}} \quad . \qquad (Eq.\ 3.4)$$

N_i = the number of observation for hospital *i* in panel data
t = time period
u_{it} = residual of hospital *i* at time period *t*
and the denominator *of* EE_i equation denotes maximum average residual from the sample of hospitals.
The average economic efficiency of Dutch hospital sector (EE) is consequently simply defined as a mean of hospitals' individual average economic efficiency EE_i

$$EE = \frac{\sum_i^N EE_i}{N} \qquad (Eq.\ 3.5)$$

where N is the number of hospitals.

3.3 The data and defining variables

Data for this study covers the years 1995 – 2002 and were provided by Centre for Innovation and Public Sector Efficiency Studies at Technical University Delft. The data were derived from a set of surveys (e.g. personnel, financial surveys) and collected by the Institute for Health Care Management (Prismant). The longitudinal data contain information on general hospitals over eight years with total of 778 observations. General hospitals represent approx. 80% of hospital beds and almost 70% of the cost of the Dutch hospital sector (Blank & Vogelaar, 2004). The number of hospitals decreases over time due to merges and closures (Blank et al., 2000) from 109 hospitals in 1995 to 87 hospitals in 2002. After elimination of missing and error causing data[13] and standardizing it for all four models, the number of observations drops to 721 (the data sample is identical for all models to avoid different statistical or economical outcomes due to different data samples). The missing but needed various financial and accountancy data negatively affected the construction of alternative capital inputs in a way that not all theoretical requirements for approximating capital input were met. The own investigation for necessary data was made. Neither Prismant nor Association of Dutch Hospitals (NVZ Vereniging van Ziekenhuizen) possesses the annual financial and accountancy data. The database of all aggregated financial and accountancy data for all hospitals *since 2007* is available at Jaarverslagen Zorg (http://www.jaarverslagenzorg.nl/), which is governed by Ministry of Health, Welfare and Sport (Ministerie van Volksgezondheid, Welzijn en Sport). This database, unfortunately, does not match our data set and therefore could not be used. Nevertheless, it offers an excellent opportunity for future research.

[13] The negative and zero values of all variables were eliminated due to the log transformation of variables in *(Eq. 3.2)*.

Production

This study considers two different units of outcome: (1) a number of *discharge*s for inpatients and day-care patients and (2) a number of first *visits* for policlinic patients. The former is based on so called final production approach, which views the hospital as a medical facility that treats patients. Another approach regards production as the volume of procedures and patient days (Blank et al., 2000). Since the latter constitutes only intermediary production as output we consider the discharges, or in other words treated cases, as the major output of hospital activity. Another viewpoint of outcome distinguishes between health and health care activities. When using health care activities for outcome evaluation (measured by either intermediate or final production approach) we implicitly assume no difference between organizations in the effectiveness (or quality!) of the activities (Jacobs et al., 2006). For instance, 2 hospitals with the same number of discharges will be treated equivalently even though the patients of one of those hospitals may systematically suffer more health complication or they are less satisfied after the discharge than those patients in another hospital. This suggests that health care outputs should be defined in terms of health outcomes produced, rather than activities undertaken. Nevertheless given the limitation of available data the health outcomes are proxied by health activities. There are several ways to assess the hospital outcomes (e.g. by employing hospital specific death rates or other quality indicator and associate these rates to hospital production). In our analysis we assume the same quality of output among hospitals.

There are in total 37 discharge health categories for inpatients, day care patients and first patient visits which are available in the data set. In order to make the measurement feasible, the range of output was limited by aggregating the discharge categories into homogenous groups (see Zuckerman et al., 1994). Following Blank & Vogelaar (2004) the discharges were aggregated into 5 groups in accordance with average stay and cost homogeneity. Each discharge category includes both inpatients and outpatients for a given specialty (e.g. allergology as a part of first group accounts for both inpatients' and day care patients' discharges). The fifth group represents the total number of outpatient (policlinic) visits deduced as the total number of hospital first patient visits minus the number of patients classified as inpatients and day-care patients. The division of health categories into 5 groups based on hospital stay and cost homogeneity is listed in Table 1.

Table 1: Five output groups

GROUP	MEDICAL SPECIALTIES	PATIENTS CATEGORY	UNIT OF OUTCOME
1	Allergology, urology, plastic surgery, gynecology, ophthalmology ,ear, nose and throat specialties, oral and dental surgery	Inpatients + day-care patients	Discharges
2	Surgery, orthopedics, neurosurgery, cardiopulmonary surgical specialties	Inpatients + day-care patients	Discharges

GROUP	MEDICAL SPECIALTIES	PATIENTS CATEGORY	UNIT OF OUTCOME
4	Internal medicine, lung specialties, clinical geriatrics, dermatology, neurology, psychiatry, rehabilitation, other and unclassified specialties	Inpatients + day-care patients	Discharges
5	All specialties	Outpatients	Patient visits

Variable cost and input prices

The cost function in hospital settings basically distinguishes 3 input prices: price of labor, material and capital (if applicable).

Price of labor is not directly available, but it can be easily approximated by the total cost for each category divided by the number of full time equivalents for the category. Essentially, there are 3 approaches of how to measure the average cost of labor force (Ludwig, 2008). We can employ average national and regional prices (in case the prices are endogenous to the hospital) or average prices for the individual hospitals. Given the fact that wages are negotiated between labor unions and Dutch association of hospital we can correctly assume that the wages are exogenous to the hospital. This assumption is consistent with Ludwig (2008) and Blank et al. (2000). Both authors used comparable data set.

The data identifies eight staff categories:

A. Administration staff
B. Management
C. Nurses
D. Student nurses
E. Paramedical personnel
F. Other personnel related to patients' care
G. Staff which can be related to hotel services provided by the hospital (e.g. cleaning or cooking)
H. Maintenance staff

The cost and prices (wages) of physicians were excluded from the study to ensure that hospitals with physicians on their payroll and hospitals with self-employed physicians are treated equally (Blank & Eggink, 2004). Unless there is a specific interest in deployment of different labor types (for example to control for relationship between efficiency and mix of labor inputs), Jacobs et al. (2006) suggest applying single measure of labor input where the various categories are weighted relatively to their mean wages. In our model the staff categories were aggregated into four groups which enable to define allocative efficiency of labor force while keeping the model parsimonious. The aggregation was based on homogeneity of wages and qualification. No weights were attached to any of the defined labor groups. The utilized data set also contains the data directly associated to labor cost, namely the payments made to or from the Dutch Sickness Fund. The Table A.2 which gives a description of the aggregated groups with their mean unit prices (mean wages) and an average number of employees per given category per hospital during the observed period is in the appendix.

Neither prices nor quantities of *material* are directly available. Therefore we approximate the prices by Consumer Price Index published by National Statistics Bureau (Centraal Bureau voor de Statistiek). The first year of observation (1995) is defined as a base year with the price of 1.0000 followed by sequence of consumer price adjustments which result in more than 20% increase in material prices in the last year of observation ($CPI_{1995}2002=1.2034$). The Consumer Price Indexes for every year are on hand in the appendix (Table A.3).

Variable costs are all costs related to variable inputs. Variable costs incorporate labor cost, material cost and capital cost (if applicable). The labor cost for all staff categories and the material cost (for example cost on food, cost related to provision of hotel services, maintenance cost) are available in the dataset. Capital cost is ignored.

Defining fixed variable: alternative approximations of capital input

As it was already mentioned there are several ways to measure capital. Given the model specification from *(Eq. 3.1)* this part defines alternative instruments for capital input quantity as fixed input.

The first instrument for the capital input utilizes the hospital beds. The number of hospital beds is a commonly used proxy for the capital input in efficiency studies (see for instance Worthington, 2004). It was either directly used for estimation of capital quantity (for example Wagstaff, 1989) or served as a variable for a computation of the capital price (e.g. Zuckerman et al., 1994). The later approach which utilizes the number of beds for derivation of the price of capital and therefore considering the beds as the capital input quantity is viewed as standardized treatment of the capital input (Rosko & Mutter, 2008). In the presented analysis no difference is made between long-term, ICU (Intensive care unit) or any other types of hospital beds. This approximation might therefore disadvantage the hospitals with the greater proportion of ICU beds than the average.

Another physical measure for the quantity of capital examined in the analysis is hospital floor space. The square footage or meters squared are regarded as an appropriate proxy for (the size of) hospital building (Coelli, 2003). This instrument for hospital's capital stock was used e.g. by Li & Roseman (2000). This method (as well as the first approach) implicitly assumes fixed proportionality of the instrument to the total capital stock across hospitals and time.

The last instrument for the capital is defined by a monetary proxy, namely by an estimation of the nominal undepreciated capital stock. This proxy is probably the only reliable monetary capital quantity instrument which can be derived from the available data. Its monetary nature connote that it captures even little changes in the capital stock, varies more significantly than the physical proxies and therefore is more precise. The accountancy data for measuring capital quantity were used for instance by Chirkos (1998) who employed (1) the book value (= nominal depreciated capital stock in a jargon used by Coelli (2003)) and (2) the value of current assets (=depreciated stock in current prices). The nominal undepreciated capital stock is routinely reported by hospital annual reports. But in this analysis the circumventing construction of nominal undepreciated capital stock was necessary due to the limitation of the used database (where the only available accountancy data regarding capital are depreciation and interest expenses). By utilizing annual depreciation amounts while considering the accountancy rules in the Dutch hospital sector the nominal undepreciated capital stock was constructed (the depreciation rates were used as weights for approximation of nominal undepreciated capital stock)[14]. Its construction, though, resulted in a small bias because it ignores scraped assets[15]. The disadvantage on nominal stock is the neglected effect of inflation (Coelli, 2003)[16].

3.4 Statistical and economic results

This chapter describes the statistical as well as economical sensitivity to various measures of capital. *Statistical properties* are mainly represented by R-squared of the main cost function and by significance of estimated coefficients. The level of significance is 5%. *Economic properties* are symbolized by estimated mean sector efficiency described in *(Eq. 3.5)* and by correlation of individual efficiency scores between alternative models described in *(Eq. 3.4)* in a certain year. The monotonicity and concavity conditions were assumed to be in compliance with theoretical requirements

The statistical properties of the estimated cost function for various capital instruments are listed in Table 2. Essentially, the R-squared are very large and similar across models. Their values are alike with the explanatory power of the cost functions employed by Blank & Vogelaar (2004). The best-fitting is the cost function which utilizes number of beds. However, the differences in R-squared are so little that they can be neglected. The cost function which defines the capital as the nominal undepreciated capital stock has the highest proportion of the significant coefficients (around 47% i.e. 34 out of 72 coefficients are significant). Only 39% of all coefficients is significant in the cost function which defines capital as the number of beds. The F-statistics proved the joint significance of a fixed capital coefficient, its square and cross terms for all cost functions, because the critical value of 1.80342 is smaller than F-statistics. The individual estimates together with p-values are shown in Table A.5 in the appendix. The coefficient which depicts the fixed capital is significant only for a cost function which defines capital as the number of beds. Its square, however, is significant for other two capital instruments (and is insignificant for the number of beds). Moreover, the estimate of the squared fixed capital that was defined as the floor space is

[14] The construction of estimated nominal undepreciated capital stock was possible due to the facts that (1) the Dutch hospitals are subjected to the same accountancy rules which (2) employ straight-line depreciation and (3) the expected asset life for every asset category is predetermined (Richtlijnen voor de Jaarverslaggeving, (2010); Jaardocument 2009. Vlietland Ziekenhuis, (2009)). The third prerequisite leads to the same depreciation rates for specific asset category among hospitals. The depreciation rates for the fixed asset categories are in Table A.4 and together with brief comments listed in the appendix.

[15] The nominal undepreciated capital stock will be overvalued because discarded assets are not taken into consideration (the annual amount of discarded assets is unknown and therefore cannot be subtracted from the constructed nominal undepreciated capital stock).

[16] By application of historical cost the hospitals that acquired the capital stock in earlier years are advantaged over the hospitals with the identical asset acquired later (by assuming inflation is greater than zero).

unexpectedly *negative* and reveals inverse relationship between the pre-defined fixed capital and the hospital cost. The convergence for all models was achieved after 10 to 13 iterations.

Table 2: Statistical properties

	Number of beds	**Floor space**	**Nom. undepr. capital stock**
R-squared	0.966578	0.966086	0.959247
% of significant coeff.	38.89%	41.67%	47.22%
F-statistics of joint significance	28.06	26.79	12.40
Number of iterations	10	13	12

The mean efficiency with standard deviation in parentheses and the minimal efficiency score are listed in Table 3. With respect to the modeling of the efficiency the maximum efficiency is equaled to 1 for all models. The deepest gap between mean efficiencies (more than 5 percentage points) is between the cost functions utilizing the number of beds and the floor space. On the other hand the mean efficiency for the model where nominal undepreciated capital stock is employed is very similar to the specification with the number of beds with the difference in the average efficiency smaller than 1 percentage point. The minimum efficiencies move in the same manner.

Table 3: The mean and minimal efficiency

	Number of beds	**Floor space**	**Nom. undepr. capital stock**
Efficiency (mean) **Std. Dev.**	0.77449 (0.069542)	0.82752 (0.071518)	0.7803 (0.076486)
Efficiency (min)	0.576	0.60603	0.56383

The rank-order correlations presented in Table 4 reveal the closest resemblance between the cost functions utilizing the floor space and the number of beds and between the floor space and the nominal undepreciated capital stock. The weak correlation is between the number of beds and the nominal undepreciated capital stock.

Table 4: Rank-order correlations

	Number of beds	**Floor space**	**Nom. undepr. capital stock**
Number of beds	1		
Floor space	0.872424	1	
Nom. undepr. capital stock	0.829796	0.877354	1

3.5* Alternative model specification

This chapter addresses important issue in the modeling of the capital input, namely its endogenity and exogeneity. All previous definitions of the capital input regarded this recourse as fixed that means the capital used is exogenous to hospital management (with respect to *(Eq. 3.1))*. Nevertheless, taking into account the situation in the Dutch hospital sector this treatment of the capital is not appropriate. The alternative model offers more sophisticated valuation of capital which reflects the actual and more realistic utilization of this resource. In the alternative model some of the assets are defined as variable input since they are assumed to be under the control of hospital management. This endogeneity is expected either due to the character of the specific asset type or due to the long time perspective. A group of the fixed assets includes ground facilities, buildings and utility lines and other installations. These assets are considered as fixed input because the author assumes that hospital management cannot change their volume with respect to production and time horizon. This assumption is based on a fact that the major capital investment (for instance in buildings) must be approved and financed by government and therefore these "investments are exogenous to hospital management" (Ludwig, 2008). The inventory (including computers) and intangible assets are defined as variable inputs by assuming that the time horizon of 8 years and the lower capital intensity allow the hospital management to change their volume with respect to production. The intangible assets like know-how (for instance practice and procedures) or intellectual property (for example patents, reputation or copyrights) (Heurer & Romero, 2007) are assumed to be endogenous to the hospital management and therefore this group is classified as variable capital input. However its classification as well as *inclusion* in the capital input is doubtful also due to the ignoring research as part of the hospital's production (see chapter Production). Table 5 offers the review of the estimated nominal undepreciated capital stock portioned into the asset categories and averaged during the 8 years.

Table 5: Asset categories of nominal undepreciated capital stock, (721 observations)

Asset	Mean	Sum	% of the total stock
ground facilities (FA)	1064376.422	767415000	1.37%
buildings (FA)	3.56342D+07	25692300000	45.73%
utility lines and other installations (FA)	1.58080D+07	11397600000	20.28%
inventory (VA)	2.13982D+07	15428100000	27.46%
computers and software inventory (VA)	1847480.194	1332030000	2.37%
Intangible fixed assets (VA)	2179086.197	1571120000	2.80%
∑FA	5.25066D+07	37857300000	67.38%
∑VA	2.54248D+07	18331200000	32.62%

Since some of the assets are variable the incorporation of its prices and cost in the cost function defined by *(Eq. 3.1)* is necessary. The hospital cost of capital should reflect the user cost of capital defined by *(Eq. 2.3)*. That means that cost of capital should incorporate depreciation cost, opportunity cost and should be expressed in present value. This model utilizes the nominal undepreciated capital stock as a proxy for quantity of capital. Depreciation cost is directly available in the dataset. The opportunity cost is derived by the multiplication of the capital stock by the long–term interest rates (listed in Table A.1). The sum of opportunity cost and depreciation cost is defined as the cost of capital. The user cost formula, however, requires an additional step i.e. the transformation of historical cost to present value. Nonetheless this step is ignored because the annual capital investments before 1995 included in the nominal undepreciated capital stock for the year 1995 cannot be revaluated in 1995-th value due to an absence of the investment series before 1995. Therefore the transformation of the years following 1995 to the present values could not be done appropriately. The price of capital is simply defined as the capital cost divided by estimated capital stock.

Evaluation of the alternative model

The alternative model not only measures the quantity of capital in most favorable way (given the data constraints) but also addresses the issue of its endogeneity. These features result in more precise and more realistic depiction of capital input utilization across the hospitals. The mean sector efficiency measured by the alternative model is 0.77145 with standard deviation of 0.080267. The minimum efficiency is 0.53677. Neither economic nor statistical properties of this model are compared to the outcomes from the chapter 3.4 due to the different model specifications.

CONCLUSION AND DISCUSSION

The aim of this thesis was to analyze different approximations of capital quantity in a hospital setting, and to scrutinize their impact on statistical properties of estimated cost function as well as subsequently measured economic efficiency. In the analysis which utilized empirical data on the Dutch general hospitals the variable cost function defined by Kumbhakar & Lovell (2003) was applied. This specification distinguishes between fixed and variable input. In the presented analysis the capital was treated uniformly as the fixed input In order to examine the effect of the alternative capital instruments.

The empirical part examines three interpretations of capital quantity, namely number of beds, the hospital's floor in meters squared and the estimated nominal undepreciated capital stock which was deduced from the annual depreciation cost. The alternative capital instruments were assessed taking into account the theoretical as well as statistical and economic properties. The statistical properties consider R-squared and the significance of the coefficients of the cost function. The economic properties include the mean and minimum sector efficiency and the rank-order correlation of the efficiency scores.

The results show that R-squared is large with negligible differences across the cost functions. In terms of the significance of the coefficients the most favorable is the cost function which defines capital as the nominal undepreciated capital stock. The special attention should be paid to square estimate "fixed capital" with negative sign in the cost function with hospital's surface. The inverse relation between the fixed capital and the total cost implies either (1) the misspecification of the model or (2) a fact that the larger the hospital (building) the lower the total cost. This finding would deserve further investigation. The most significant gap in the mean efficiencies is between the model which utilizes the floor space and the model with the number of beds or the nominal undepreciated capital stock, respectively. The number of beds and the nominal undepreciated capital stocks constitute very similar mean efficiency scores. Since the nominal undepreciated capital stock is viewed as the instrument with the best theoretical properties the number of beds might therefore better reflect the capital quantity in a hospital than the floor space. This is in compliance with the theoretical backgrounds of the alternative instruments. Nevertheless the rank-order correlation of the individual efficiency scores is the lowest between the model considering the number of beds and the model with the nominal undepreciated capital stock and thus their closest relationship is contradicted. Models that apply the square meters and hospital beds are similar in the order of their efficiency scores. By closer investigation of the data it was discovered that those two variables are relatively constant for the hospital during the observed time. On the other hand the nominal undepreciated capital stock fluctuates more during the time. This tendency might be the cause of the similarity or dissimilarity in the rank-ordering. To sum up the most appropriate proxy from the examined capital instruments is the nominal undepreciated capital stock. This conclusion is in compliance with Coelli (2003) who suggests utilizing monetary rather than physical proxies. If the accountancy data for their construction is not available the number of beds seems to be better instrument for the capital stock since the hospital's floor space is associated mainly with the size of the building rather than with the volume of production or the capital stock.

Additionally, the proper treatment of capital requires the assessment of its exo- and endogeneity, respectively. Therefore an alternative model was developed which regards certain assets as the variable input taking into account the time perspective and the regulation in the Dutch hospital sector. The endogeneity of those assets leads to the inclusion of their cost and price into the cost function. Instead of interest expenses the cost of capital considers the opportunity cost. This approach follows the theoretical prerequisites defined by the User cost formula (OECD, 2001a) instead of the common practice (see for instance Rosko & Mutter, 2008).

In conclusion the various approximation of the capital input in cost efficiency analysis result in the inconsistent changes in the mean efficiency of the hospital sector and in the ranking of the hospital's individual performance. This finding indicates relatively high sensitivity of efficiency outcomes to the definition of the capital input. The recommendation for researchers is to maximally follow the theoretical requirements for the definition of capital input. To reflect the actual utilization of the resource the Perpetual Inventory Method appeal to be the best method for measurement of capital input quantity. The major obstacle for its application is the availability of data, though. In Dutch hospital sector implications, however, this obstacle can be overcome. The database of all aggregated financial and accountancy data for all hospitals since 2007 has been created and it is available at Jaarverslagen Zorg. The utilization of this data for future research is thus *strongly* recommended.

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APPENDIX

Health Care Expenditures

According to OECD (2010b) the total health spending accounted for 9.9% of GDP in the Netherlands in 2008, which was higher than the average of 9.0% in OECD countries. In terms of nominal prices the expenditures more than doubled during the observed 13 years starting from 25420 euro per capita in 1995 and approaching to 58775 euro in 2008. The development of total health expenditures (both in nominal prices and as a percentage of GDP) is illustrated in Chart 1. Despite this development the spending remains much lower than in the United States, Norway or Switzerland. Health spending was predominantly funded by public sources (82.1% in 2008), well above the OECD average of 72.8% (in 2008).

Chart A.1, Total expenditure on health in the Netherlands. Source: OECD (2010a)

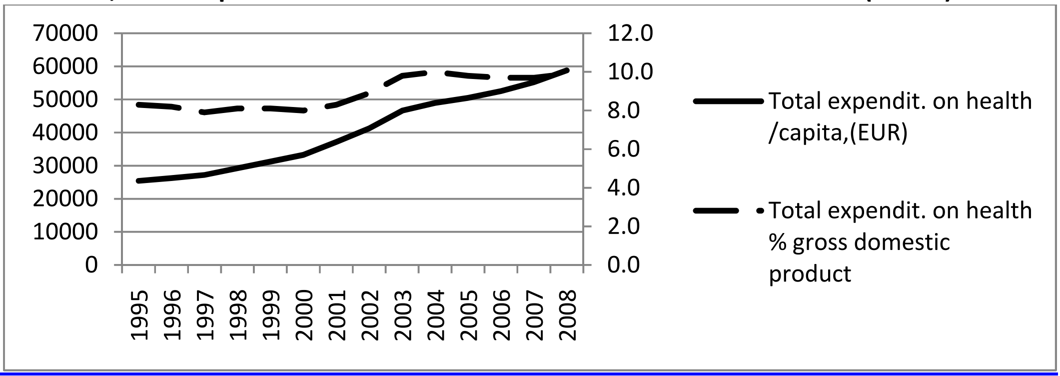

Table A.1: Long-term interest rates[17] in the Netherlands, Per cent per annum. Source: OECD (2010c).

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
LT-IR	6.899167	6.150833	5.576667	4.631667	4.629167	5.405	4.958333	4.89

Table A.2: Aggregated staff groups description

GROUP	AGGREGATED CATEGORIES	MEAN WAGE	AVERAGE NUMBER OF EMPLOYEES IN HOSP.
1.	Administration staff group (=administration + management)	33602	172
2.	Nurses staff group (=nurses+ student nurses)	33929	442
3.	Paramedical staff group (=paramedics+ other staff related to patients)	36408	248
4.	Maintenance staff group (=maintenance +”hotel” staff)	27736	157

[17] Long term interest rates are secondary market yields of long term (usually 10 year) bonds (OECD, 2003c).

Table A.3: Consumer price index from 1995 to 2002. Source: CBS (2010)

Consumer prices; price index 1995 = 100			
Subjects_1	**Periods**	**Unit**	
CPI	1995	1995 = 100	**1.000000**
CPI	1996	1995 = 100	**1.021058**
CPI	1997	1995 = 100	**1.043079**
CPI	1998	1995 = 100	**1.063121**
CPI	1999	1995 = 100	**1.086157**
CPI	2000	1995 = 100	**1.113255**
CPI	2001	1995 = 100	**1.164351**
CPI	2002	1995 = 100	**1.203421**

Depreciation rates for the capital assets

The dataset distinguishes between tangible and intangible fixed assets. The fixed tangible assets are further separated in five categories

- ground facilities (e.g. roads, pavements, outdoor lighting)
- buildings
- utility lines and other installations (e.g. air conditioning, heating, electricity network)
- inventory (e.g. medical equipment, furniture)
- computers and software (this group is a part of inventory)

Tangible fixed assets use different depreciation rates which depend on their different asset life. Intangible assets are not further specified and use just one rate of 10%. The depreciation for buildings is either 2% (for new buildings) or 5% (for old building). Because of the limited data we use their arithmetical average depreciation rate of 3.5 %. Computers and software are part of the inventory. Our dataset identifies each group in order to apply different depreciation rates.

Table A.4: Depreciation rates for various assets. Source: Richtlijnen voor de Jaarverslaggeving (2010)

1. Tangible fixed assets	
➢ **ground facilities**	5%
➢ **buildings**	2% or 5%
➢ **utility lines and other installations**	5%
➢ **inventory**	10%
➢ **computers and software**	20%
2. Intangible fixed assets	10%

Printed cost function of the alternative model with highlighted restrictions of homogeneity one in prices. The model specification is described by *(Eq. 3.2)*. In the alternative model the m =5, n=6, o=1 and p = 8.

LN(VC) = A0 + B1*LN(Y1) + B2*LN(Y2) + B3*LN(Y3) + B4*LN(Y4)
+ B5*LN(Y5) + 0.5000*B11*LN(Y1)*LN(Y1) + B12*LN(Y1)*LN(Y2)
+ B13*LN(Y1)*LN(Y3) + B14*LN(Y1)*LN(Y4) + B15*LN(Y1)*LN(Y5) + 0.5000*B22*LN(Y2)*LN(Y2) +
B23*LN(Y2)*LN(Y3) +
B24*LN(Y2)*LN(Y4) + B25*LN(Y2)*LN(Y5) +
0.5000*B33*LN(Y3)*LN(Y3) + B34*LN(Y3)*LN(Y4) + B35*LN(Y3)*LN(Y5) +
0.5000*B44*LN(Y4)*LN(Y4) + B45*LN(Y4)*LN(Y5) +
0.5000*B55*LN(Y5)*LN(Y5) + **(1 - C2 - C3 - C4 - C5 - C6)***LN(W1) +
C2*LN(W2) + C3*LN(W3) + C4*LN(W4) + C5*LN(W5) + C6*LN(W6) + 0.5000***(-C12
C13 - C14 - C15 - C16)***LN(W1)*LN(W1) + C12*LN(W1)*LN(W2) +
C13*LN(W1)*LN(W3) + C14*LN(W1)*LN(W4) + C15*LN(W1)*LN(W5) +
C16*LN(W1)*LN(W6) + 0.5000***(-C12 - C23 - C24 - C25 - C26)***LN(W2)*LN(W2) +
C23*LN(W2)*LN(W3) + C24*LN(W2)*LN(W4) + C25*LN(W2)*LN(W5) +
C26*LN(W2)*LN(W6) + 0.5000***(-C13 - C23 - C34 - C35 - C36)***LN(W3)*LN(W3) +
C34*LN(W3)*LN(W4) + C35*LN(W3)*LN(W5) + C36*LN(W3)*LN(W6) +
0.5000***(-C14 - C24 - C34 - C45 - C46)***LN(W4)*LN(W4) + C45*LN(W4)*LN(W5) +
C46*LN(W4)*LN(W6) + 0.5000***(-C15 - C25 - C35 - C45 - C56)***LN(W5)*LN(W5) +
C56*LN(W5)*LN(W6) + 0.5000***(-C16 - C26 - C36 - C46 - C56)***LN(W6)*LN(W6) +
D1*LN(Z1) + 0.5000*D11*LN(Z1)*LN(Z1) +
(-E12 - E13 - E14 - E15 - E16)*LN(Y1)*LN(W1) +
E12*LN(Y1)*LN(W2) + E13*LN(Y1)*LN(W3) + E14*LN(Y1)*LN(W4) +
E15*LN(Y1)*LN(W5) + E16*LN(Y1)*LN(W6) + **(-E22 - E23 - E24 - E25 -
E26)***LN(Y2)*LN(W1) + E22*LN(Y2)*LN(W2) + E23*LN(Y2)*LN(W3) +
E24*LN(Y2)*LN(W4) + E25*LN(Y2)*LN(W5) + E26*LN(Y2)*LN(W6) + **(-E32 - E33
E34 - E35 - E36)***LN(Y3)*LN(W1) + E32*LN(Y3)*LN(W2) +
E33*LN(Y3)*LN(W3) + E34*LN(Y3)*LN(W4) + E35*LN(Y3)*LN(W5) +
E36*LN(Y3)*LN(W6) + **(-E42 - E43 - E44 - E45 - E46)***LN(Y4)*LN(W1) +
E42*LN(Y4)*LN(W2) + E43*LN(Y4)*LN(W3) + E44*LN(Y4)*LN(W4) +
E45*LN(Y4)*LN(W5) + E46*LN(Y4)*LN(W6) + **(-E52 - E53 - E54 - E55 -
E56)***LN(Y5)*LN(W1) + E52*LN(Y5)*LN(W2) + E53*LN(Y5)*LN(W3) +
E54*LN(Y5)*LN(W4) + E55*LN(Y5)*LN(W5) + E56*LN(Y5)*LN(W6) +
(-F12 - F13 - F14 - F15 - F16)*LN(Z1)*LN(W1) +
F12*LN(Z1)*LN(W2) + F13*LN(Z1)*LN(W3) + F14*LN(Z1)*LN(W4) +
F15*LN(Z1)*LN(W5) + F16*LN(Z1)*LN(W6) +
G11*LN(Z1)*LN(Y1) + G12*LN(Z1)*LN(Y2) + G13*LN(Z1)*LN(Y3) +
G14*LN(Z1)*LN(Y4) + G15*LN(Z1)*LN(Y5) + A1*TIME1 +
A2*TIME2 + A3*TIME3 + A4*TIME4 + A5*TIME5 + A6*TIME6 + A7*TIME7 + A8*TIME8.

Table A.5: The estimates and their P-values of the cost functions with alternative capital instruments

		Number of beds		Floors pace		Nom.undepr.cap.stock	
	Parameters estimated	Estimate	P-value	Estimate	P-value	Estimate	P-value
A0	constant	1.11E+01	[.000]	2.86153	[.054]	3.764	[.366]
A2	2nd year	-0.010131	[.390]	-7.76E-03	[.542]	-0.03424	[.018]
A3	3rd year	-8.20E-03	[.506]	0.010561	[.438]	-0.05304	[.000]
A4	4th year	0.020763	[.104]	0.041477	[.003]	-0.0386	[.011]
A5	5th year	-0.017804	[.238]	-2.05E-03	[.902]	-0.10672	[.000]
A6	6th year	1.11E-02	[.478]	0.012026	[.479]	-0.1056	[.000]
A7	7th year	0.038928	[.017]	0.032224	[.065]	-0.09562	[.000]
A8	8th year	5.91E-02	[.001]	0.032816	[.068]	-0.11575	[.000]
B1	Output Group1	-2.30E-02	[.961]	0.926758	[.038]	1.6851	[.056]
B2	Output Group2	-1.41E+00	[.008]	-0.08296	[.862]	0.803092	[.343]
B3	Output Group3	-1.67E-01	[.476]	-1.08561	[.000]	-2.19986	[.000]
B4	Output Group4	-6.12E-01	[.208]	0.220377	[.607]	-0.05985	[.931]
B5	Output Group5	-4.92E-01	[.198]	0.03472	[.918]	1.33967	[.027]
B11	Output Group1 x Output Group1	3.91E-01	[.008]	0.316535	[.042]	0.46173	[.010]
B12	Output Group1 x Output Group2	-1.74E-01	[.092]	0.038016	[.740]	0.302643	[.017]
B13	Output Group1 x Output Group3	-4.74E-02	[.296]	0.047565	[.336]	-0.02633	[.636]
B14	Output Group1 x Output Group4	-2.11E-02	[.830]	-0.15838	[.110]	-0.19592	[.075]
B15	Output Group1 x Output Group5	-1.06E-01	[.191]	-0.19516	[.018]	-0.27425	[.005]
B22	Output Group2 x Output Group2	5.85E-01	[.003]	0.545648	[.005]	0.162687	[.437]
B23	Output Group2 x Output Group3	-4.13E-02	[.505]	8.19E-03	[.904]	0.037643	[.631]
B24	Output Group2 x Output Group4	-1.66E-01	[.175]	-0.33923	[.005]	-0.14303	[.265]
B25	Output Group2 x Output Group5	-4.41E-03	[.958]	-0.16399	[.064]	-0.07393	[.483]
B33	Output Group3 x Output Group3	1.80E-02	[.440]	-0.02099	[.394]	2.64E-03	[.927]
B34	Output Group3 x Output Group4	-1.36E-02	[.820]	-0.02328	[.618]	-0.02394	[.634]
B35	Output Group3 x Output Group5	2.05E-03	[.965]	0.027744	[.551]	-0.04414	[.453]
B44	Output Group4 x Output Group4	1.12E-01	[.303]	-2.81E-03	[.979]	0.191802	[.081]
B45	Output Group4 x Output Group5	1.24E-01	[.084]	0.105875	[.143]	0.057791	[.476]
B55	Output Group5 x Output Group5	0.253863	[.003]	0.198406	[.032]	0.601902	[.000]

		Number of beds		Floors pace		Nom.undepr.cap.stock	
C2	Wages nurses group	6.50E-01	[.000]	0.765644	[.000]	0.851673	[.000]
C3	Wages paramedical group	-4.27E-01	[.000]	-0.48478	[.000]	-0.57311	[.000]
C4	Wages maintenance group	4.61E-01	[.000]	0.473668	[.000]	0.490283	[.000]
C5	Price material	7.47E-01	[.000]	0.6066	[.000]	0.589306	[.000]
C15	Wages administration group x Price material	-4.36E-02	[.000]	-0.04019	[.000]	-0.04107	[.000]
C25	Wages nurses group x Price material	0.014059	[.031]	0.020667	[.001]	0.013864	[.020]
C35	Wages paramedical group x Price material	-4.45E-02	[.000]	-0.04203	[.000]	-0.03378	[.000]
C45	Wages maintenance group x Price material	2.48E-02	[.000]	0.026021	[.000]	0.024846	[.000]
C14	Wages administration group x Wages maintenance group	6.35E-03	[.173]	5.46E-03	[.233]	5.98E-03	[.193]
C24	Wages nurses group x Wages maintenance group	-0.014563	[.004]	-0.01442	[.004]	-0.01159	[.021]
C34	Wages paramedical group x Wages maintenance group	-2.72E-03	[.574]	-2.23E-03	[.645]	-7.29E-03	[.142]
C13	Wages administration group x Wages paramedical group	2.04E-02	[.000]	0.020489	[.000]	0.018019	[.000]
C23	Wages nurses group x Wages paramedical group	-2.90E-02	[.000]	-0.03285	[.000]	-0.03862	[.000]
C12	Wages administration group x Wages nurses group	-1.37E-02	[.010]	-0.01646	[.002]	-0.01419	[.007]
D1	Fixed capital	2.98E+00	[.000]	0.598818	[.107]	-0.74985	[.256]
D11	Fixed capital x Fixed capital	1.75E-02	[.926]	-0.2419	[.001]	0.269139	[.000]
E52	Output Group5 x Wages nurses group	-1.71E-02	[.000]	-0.01645	[.000]	-6.39E-03	[.132]
E53	Output Group5 x Wages paramedical group	9.91E-03	[.017]	0.010067	[.016]	-1.05E-04	[.980]
E54	Output Group5 x Wages maintenance group	-1.10E-02	[.000]	-0.01041	[.000]	-9.23E-03	[.001]
E55	Output Group5 x Price material	4.13E-03	[.242]	3.05E-03	[.389]	6.13E-04	[.868]
E42	Output Group4 x Wages nurses group	-1.27E-03	[.800]	2.36E-03	[.606]	-9.15E-04	[.832]
E43	Output Group4 x Wages paramedical group	-8.35E-03	[.096]	-6.47E-03	[.164]	-3.93E-03	[.366]
E44	Output Group4 x Wages maintenance group	3.87E-03	[.226]	2.54E-03	[.393]	3.40E-03	[.231]
E45	Output Group4 x Price material	6.16E-03	[.155]	4.94E-03	[.222]	6.02E-03	[.117]
E32	Output Group3 x Wages nurses group	8.37E-03	[.002]	7.05E-03	[.009]	9.89E-03	[.000]
E33	Output Group3 x Wages paramedical group	3.56E-03	[.193]	5.36E-03	[.049]	2.38E-03	[.371]
E34	Output Group3 x Wages maintenance group	-2.51E-03	[.144]	-2.58E-03	[.133]	-2.31E-03	[.178]
E35	Output Group3 x Price material	-1.53E-02	[.000]	-0.01484	[.000]	-0.01543	[.000]
E22	Output Group2 x Wages nurses group	3.06E-03	[.618]	9.29E-03	[.108]	2.79E-03	[.597]
E23	Output Group2 x Wages paramedical group	-9.97E-04	[.870]	-1.02E-04	[.986]	5.16E-03	[.333]
E24	Output Group2 x Wages maintenance group	-4.07E-03	[.288]	-6.02E-03	[.103]	-4.71E-03	[.169]

		Number of beds		Floors pace		Nom.undepr.cap.stock	
E25	Output Group2 x Price material	2.42E-03	[.648]	-1.43E-04	[.978]	1.63E-03	[.728]
E12	Output Group1 x Wages nurses group	-4.51E-03	[.410]	-1.49E-03	[.780]	-3.16E-04	[.952]
E13	Output Group1 x Wages paramedical group	-6.27E-03	[.252]	-6.29E-03	[.245]	-8.27E-03	[.117]
E14	Output Group1 x Wages maintenance group	4.87E-03	[.155]	4.06E-03	[.234]	5.21E-03	[.124]
E15	Output Group1 x Price material	8.26E-03	[.081]	7.12E-03	[.130]	7.23E-03	[.119]
F12	Fixed capital x Wages nurses group	-8.31E-03	[.199]	-0.01912	[.000]	-0.02305	[.000]
F13	Fixed capital x Wages paramedical group	2.34E-02	[.000]	0.01754	[.000]	0.024505	[.000]
F14	Fixed capital x Wages maintenance group	-2.23E-03	[.591]	1.42E-03	[.582]	-3.10E-03	[.166]
F15	Fixed capital x Price material	-8.41E-04	[.879]	4.16E-03	[.232]	4.01E-03	[.194]
G11	Fixed capital x Output Group1	-2.65E-02	[.799]	-0.08315	[.344]	-0.18779	[.036]
G12	Fixed capital x Output Group2	-1.15E-02	[.930]	-0.01575	[.860]	-0.15679	[.050]
G13	Fixed capital x Output Group3	1.48E-01	[.005]	0.069043	[.118]	0.15554	[.001]
G14	Fixed capital x Output Group4	3.15E-02	[.773]	0.312781	[.000]	0.068876	[.321]
G15	Fixed capital x Output Group5	-3.41E-01	[.000]	5.54E-03	[.934]	-0.25736	[.000]