HOSPITAL COST FUNCTIONS AND QUALITY

by

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(ABSTRACT)

This study examines the significance of quality when included in the specification of a hospital cost function. Also, this research estimates a value for scale economies in order to determine if the average hospital experiences increasing returns to scale in the production of hospital care, verifying such findings in previous econometric studies. Furthermore, two functional forms are compared: the Cobb-Douglas and the translog.

The results of this study demonstrate that quality has a significant impact on costs. This relationship is positive meaning increasing quality will also increase the cost of producing hospital care. The results for scale economies demonstrate that the average hospital experiences increasing returns to scale in the production of hospital care, which is consistent with previous research. Lastly, based on an *F*-test, this study is able to accept the translog as the appropriate functional form.

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Contents

List of Tables

1. Introduction

Quality of hospital care is an important factor in consumer choice. Individual consumers consider quality when purchasing goods or services. It is also important for the attainment of payer contracts as well as industry accreditation.[1] Econometric studies of hospital cost functions have primarily focused on influences on cost such as size, scale economies, chain membership, etc., while little or no work has been done on the relationship between cost and the quality of hospital care.

This paper will develop a model for estimating total hospital cost while including quality considerations. Typically, the problem of excluding quality variables stems from the difficulty in obtaining data. In addition to factors traditionally considered important to hospital cost (output, wage rates, capital, and supplies) this study considers two quality variables: nursing hours, and risk adjusted mortality rates. In analyzing these different indicators, the central question is - will either of these measures have a significant impact on costs? If so, what is that effect? Is quality costly, or, is it unimportant in cost considerations? Furthermore, this study will attempt to verify the findings for scale economies found in previous econometric studies.

The paper is organized as follows. The remainder of Section 1 discusses the trend in hospital costs and quality. Section 2 reviews the literature and provides the theoretical framework behind this study. In Section 3 this research develops a model and specifies a function for hospital cost while Section 4 discusses the data used in this study. Section 5 discusses empirical results and Section 6 summarizes the study.

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[1] Contracts negotiated between medical provider and insurance company to provide services at a discount in return for guaranteed referrals.

1.1 Cost and Quality in the Hospital Industry

The following section provides information regarding the trend in the hospital industry with respect to cost and quality. The following sections intend to provide the reader with background information as to why cost and quality in healthcare are important. The first section discusses managed care and its impact on cost, followed by Section 1.1.2, which discusses quality.

1.1.1 The Growth of Managed Care

During the post World War II era, healthcare delivery has experienced tremendous change. First, new technologies have changed the way healthcare is delivered by introducing over time more sophisticated techniques for diagnosing and treating illnesses (Weisbrod, 1991). Second, the role of healthcare insurance has expanded dramatically. By 1980, 82.5 percent of Americans had some sort of health insurance (Weisbrod, 1991). Weisbrod argues the expansion of healthcare insurance and the reliance on third party payers for healthcare expenditures have paid for the development of these new and expensive technologies. With this, the cost of providing medical care has risen dramatically. For example, average hospital cost per case in California rose 74.5 percent in the years 1982 to 1988 (Enthoven, 1991). In response to rising medical costs, managed care plans have grown tremendously. As much as 50 percent of the population in some areas of California are enrolled in an HMO (Hospital and Health Networks, January, 1998).[2]

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[2] HMO's or Health Maintenance Organizations, are insurance companies that provide insurance coverage and require their enrollees to use their facilities or facilities they contract with.

Managed care plans control costs in that they provide greater price competition among healthcare providers. These plans have introduced cost saving methods of supplying health insurance by contracting with healthcare providers which provide services at reduced fees.[3] The benefit to the physician is that the plan will maintain the doctor on an exclusive list of “in- plan” doctors that the enrollee must use. This form of contractual arrangements between plan and provider extends further, from hospitals to laboratories, pharmacies, physical medicine, etc. Some HMO’s provide “in-house” services whereby the plan owns the facility and hires its doctors, nurses, and technicians and is able to manage its own costs of providing care. In effect, the managed care industry has provided not only a cost efficient mechanism for providing healthcare, but perhaps increased competition among providers to obtain these contracts. Consequently, concerns have risen as to whether the quality of care provided by hospitals has deteriorated due to increased cost cutting.

1.1.2 Quality in Healthcare

Although quality is an important factor in the production of healthcare services, it is difficult to quantify. To different people it may mean different things: how kind and caring is the nurse, how attractive is the facility, how good is the doctor in his abilities, is the bed clean, etc. Quality measures are not only difficult to obtain, but to define as well. Moskowitz (1994) lists the common responses from surveys regarding what individuals would most desire from a healthcare provider. They include: responsiveness to urgent medical situations, referral to appropriate level of care, humanness, communication information, coordination and continuity of care, primary prevention, case finding,

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[3] A healthcare provider may charge reduced fees to insurance companies for services based on a pre-negotiated contract. Depending on the negotiating power of the health plan, the size of the discounts may vary.

evaluation of present complaint, diagnosis, and proper management of the condition. Unfortunately, the author describes the data for these measures of quality “spotty” at best. Moskowitz continues to explain that rankings of quality are derived primarily from mortality rates, or death rates, which measure the probability of death. But the pervasive problem with this measure is different patients have different conditions which may or may not contribute to their likelihood of death.

In a study done in 1997, the Office of Statewide Health Planning and Development in California measures risk adjusted mortality rates for heart attack patients. Their measure is risk adjusted where patient age, sex, type of heart illness, and chronic diseases are used to adjust for differences in patient risk when calculating hospital mortality rates (Office of Statewide Health Planning and Development, 1997). California is one of the few states to carry such a comprehensive report on risk adjusted mortality rates. Their primary goal is to improve the quality of care provided to its residents by establishing a means by which hospitals can evaluate their procedures and study those of other institutions with lower rates.

Section 2 will discuss in greater detail the use of a different quality indicator - nursing hours. This quality indicator is directly related to one of the largest inputs utilized in the delivery of healthcare – nurses.

2. Literature Review

There is a wealth of literature on hospital cost functions. Most studies involve analyzing the effects on hospital cost with output, size, wages, admissions, discharges, and other factors. None, to the best of the author's knowledge, consider the economic implications of quality on cost. In this section, literature dedicated to estimating hospital cost functions will be reviewed. From these studies this paper will build the groundwork for the model, selectivity of the appropriate variables, functional form, and the type of data that should be used. Expanding the literature search, two studies of the nursing home industry that examine quality are reviewed, which lay the foundation for quality considerations used in this study.

Sections 2.1 and 2.2 review the literature and discuss the methods used for specifying and estimating a cost function and what conclusions the researchers make based on the results. Section 2.3 discusses the findings from the literature and how they apply to this study.

2.1 Hospital Cost Function Literature

In an earlier study, Bays (1980) examines specification error in hospital cost functions. He explains that previous studies focus primarily on the nature and existence of scale economies, and, these studies have concluded that average cost declines slightly with increases in size. Then, with sizes greater than approximately 200 beds, there are constant or increasing returns to scale. Bays criticizes these studies for ignoring physician input, and devotes the rest of his study to addressing the need for a physician variable, a method for estimating the quantity of physician labor, and exploring hospital cost function estimates which include and exclude the input of admitting physicians. Moreover, the Bays paper is insightful into the specification of a hospital cost function.

Bays explains that although physicians are typically not employed by hospitals and draw no salaries from them, they provide a major source of the labor necessary to produce patient care. Thus, estimating a cost function without representing physician labor is ignoring a crucial part of the production process. Possible reasons given for ignoring physician input in previous studies are the absence of data in traditional data sources since they focus primarily on providing data on the hospital component of patient care, and incomplete conceptualization of the nature of the hospital.

The author acknowledges the difficulty in obtaining physician input data. For his study he uses an index, which is based on the median fees actually charged for different procedures done by practicing physicians. Unfortunately, this measure does not capture routine care provided, rather, specialized procedures. Nevertheless, Bays uses this data to determine if physician input alters the results of a hospital cost function. The complete data set consists of California data on 41 short term, general hospitals for the years 1971 and 1972.

Bays runs regressions on two cost functions: one without physician input, and another including an imputed value for admitting physician services. The variables include: the dependent variable average cost, bed size, case flow per bed, case mix, and a measure for physician input. He concludes that his results show previous conclusions demonstrating average cost decreases up to moderately sized hospitals then increases as the hospital becomes larger is a failure to account for physician input, and physician input may be less effectively managed as hospital size increases. Bays concedes that his data on physician input are crude, but his results do imply cost per case increase with bed size when a physician input is included. Nevertheless, research on hospital cost functions dated after this study, consistently include a physician variable.

Cowing and Holtmann (1983), develop and estimate a multi-product, short-run hospital cost function. They also test several of the results concluded in previous studies such as economies of scale and economies of scope. Their model is defined as:

$$C = G(Y, p', K, A),$$

where C is short-run total variable cost, Y is a vector of outputs, p' is a vector of variable input prices which includes nurse labor, aid labor, professional labor, administrative labor, general labor, and materials and supplies. K is a vector of fixed capital inputs, and A is the number of physicians in each hospital, which is included based on the conclusions in Bay's study discussed above. Since the hospital is assumed to be a multi-product firm, Y is a vector of different outputs including inpatient hospital care and emergency room visits rather than one single measure of output. The authors emphasize the importance of input prices and they note exclusion of input price variables in previous studies assumes, in the model, that these prices are equal across all hospitals, which is likely not to be the case.

The model is specified using a translog cost function and the data includes 138 short-term, general hospitals for observations made in the year 1975. The results are as follows: elasticities for output showed a positive relationship with cost, there are economies of scope, and finally, there are economies of scale with respect to cost.

Important points from this study are that if specifying a total cost function for hospitals, the multi-product nature must be considered. Variables for output should reflect different outputs for different departments of the hospital. Cowing and Holtmann (from hereon referred to as C&H) choose patient days for various inpatient departments and emergency room visits as measures of output. They stress input prices for labor, supplies, and capital should be included in the model, which many studies tend to ignore. Finally, C&H describe the need for a physician variable since doctors are an integral part of the care delivery, yet they are typically not on the hospital's payroll. They argue exclusion can lead to specification error and use the total number of admitting physicians per hospital for the physician variable.

Menke (1997) studies the effect of chain membership on hospital costs. He uses hospital cost functions to study what effect chain membership has on hospital cost as opposed to individual ownership. The study tests the hypothesis that multi-hospital system operate more efficiently, or less costly than independently owned facilities. The model is defined as:

$$C = C(Y, P, Z),$$

where C is total cost, Y is a vector of outputs accounting for a multi-product firm, P is input price, and Z is a list of vector of variables that shift the cost function. As discussed above, this study accounts for a multi-product firm and output is represented by three different variables that include patient days, emergency room visits, and outpatient visits. Input price P includes wages. The Z variables are a number of factors effecting cost and include: discharges by payer, ownership, location, teaching, Herfindahl index, number of doctor's per capita, number of services, quality, location, and region. The cost function is specified with a hybrid translog function that allows for zero input levels and the inclusion of a variety of factors that can shift the cost function.

Regressions are run for chain and independently owned hospitals and the following results are obtained. Among independently owned hospitals, proprietary hospitals have the highest costs, followed by nonprofit and public hospitals. For chain owned hospitals, no differences in cost are found to be significant among the different ownership categories. Teaching hospitals demonstrate no differences with non-teaching and average incremental cost per outpatient visit is lower for chain hospitals. Diseconomies of scale exist for both chain and independent hospitals at low and medium level of patient days, although total cost does get flatter with increased output and economies of scale occur at very high volumes. Although quality is included as a variable in the regression, no discussion is provided in the results regarding its effect on cost. Finally, economies of scope between inpatient and outpatient care occur at all volumes for chain hospitals and up to the mean for independent hospitals.

Menke concludes that chain hospitals are more efficient than independent hospitals. Possible reasons may be that chain hospitals have a greater advantage in purchasing power, share inputs, lower capital costs, and better non-pecuniary benefits for employees. Furthermore, Menke suggests the ability of chain owned hospitals to maintain lower costs means a form of cost reduction in the marketplace especially in the wake of the death of federally mandated healthcare reform.

2.2 Studies Using Quality

The following studies of nursing home cost functions are key pieces to building the framework for including quality variables in this paper. Since the hospital cost function literature review proved inadequate with studies focusing on quality, the literature search was expanded to industries similar in nature producing the following discussion.

Gertler and Waldman (1992) study the effects of quality on cost for the nursing home industry. Their study develops a model for specifying nursing home cost. Furthermore, they include quality in the model. Following the work of Brautingham and Pauly (1986) they include endogenous and unobserved quality in their nursing home cost function. They define nursing home cost as a function of output, quality and factor input prices:

$$C=C(Y, Q, W),$$

where

$$Q=Q(Y, W, Z),$$

where C is total cost, Y is output, Q indicates quality, and W is a vector of factor input prices. Q is endogenously determined and includes Z: a set of demand variables that affect the demand curve.

This model shows that quality is affected by both exogenous supply and demand factors, whereas cost is determined by output, quality, and input prices. Therefore, quality variation is reflected by the variation in cost across firms that are correlated to exogenous determinants of product demand. Or, as the authors state, “it reflects a firm’s quality responses to different demand structures”. The input prices include wage rates for skilled and unskilled labor and the cost of supplies. The Z variables included: an index for case mix, the Medicaid plus factor, population greater than 65, and per capita income. Y, or output, is measured by patient days.

They estimate their model using a flexible functional form - the translog cost function. The data used are from a 1980 survey of New York Nursing homes and include 279 observations. Based on their regressions, one of their findings is that as the marginal cost of quality rises, firms reduce quality. Also, they find in the case where quality is not included (case where quality is not observed but assumed to be absorbed by the error term) economies of scale is calculated to be 0.061, which implies that doubling patients will reduce average cost by approximately 6 percent. In the quality-adjusted case where quality is treated endogenously, scale economies is calculated by running regressions for low, average and high quality. The results show economies of scale for low quality homes, constant returns to scale for average, and decreasing returns to scale in high quality settings. Thus, higher quality is produced through labor intensive practices (Gertler and Waldman, 1992). Furthermore, based on the cost elasticity of quality a policy-cost quality elasticity is formulated and from that they conclude policies designed to improve quality, such as promoting competition in the industry, are relatively expensive. However restricting competition would reduce costs without a large effect in the reduction in quality. Furthermore, they conclude that increases in the Medicaid reimbursement rate can decrease the level of quality by very little while allowing greater access to care for patients and lowering costs.

Mckay (1988) also estimates a cost function for the nursing home industry. Her study focuses on determining if there are scale economies in the nursing home industry. In developing the model, Mckay specifies that nursing home cost is a function of output (measured by patient days), nursing aid wages, nurse wages, building and equipment, and other services provided. In order to obtain a non-biased estimate of scale economies, Mckay argues that the cost function must control for quality differences. Consistent with discussion in the previous section, she acknowledges quality measures are difficult to obtain and her approach is to use a proxy for quality in the form of nursing hours. Mckay cites previous work that determines nursing hours is significant in determining patient outcomes and she therefore uses this as her quality variable. She defines quality as being equal to nursing hours per patient days, or $Q = NH/Y$. The cost function then becomes:

$$C = C(Y, P_A, P_B, P_S, Q),$$

where Y equals patient days, P_A is nurse aid wage, P_B is building and equipment, P_S represents the price of other services, and Q is quality that is a function of nursing hours per patient days (NH/Y).

Mckay strongly argues that a translog cost function is the most appropriate functional form for estimating this model since it allows for variable elasticity and homogeneity of degree one may be imposed on input prices. Her results focus on economies of scale in nursing home care and she concludes that nursing homes producing more patient days of care also have lower costs. Thus, there are real economies of scale in the production of nursing home care and a policy implication is in the long run, fewer, larger homes could provide the same care at a lower cost.

2.3 Conclusions and Theory Derived from the Literature

The preceding sections surveyed the literature and focused on studies representing the relevant theory needed in this study. This section is dedicated to summarizing some of the important considerations made in the literature and what influences it has on this paper.

The hospital cost function literature provides us with the framework necessary to develop a model for hospital cost. The studies reviewed provide the essential elements that need to be included in the cost function. For example, C&H and Menke treat the hospital as a multi-product firm, thus, this paper will include variables reflecting different services provided by the typical hospital. Also, every researcher has stressed the need to include factor input prices, such as wages, in the model. Failure to do so could lead to specification errors. Furthermore, Bays in his piece determines a variable reflecting physician input in the production of hospital care is necessary. Consequently, the two studies that are post Bays (C&H, 1983, Menke, 1997) include a physician variable measured by the total number of admitting physicians per hospital. Also, these studies provide a base for the expected results. For example, all three of the hospital cost function studies found increasing returns to scale in the production of hospital care. Thus, this study will also examine scale economies.

Since the literature involving hospital cost functions does not provide any research where quality is examined in hospital cost functions, other industries are searched. Two studies where quality is included in nursing home cost functions are found to be relevant to the question set forth in this paper. And, this study borrows upon those works for studying the effect quality has on hospital cost. In particular, Mckay (1989) uses a proxy for quality in the form of nursing hours per patient days. This study will use the same proxy since the healthcare literature is prolific in studies examining the effect the number of nurses have on quality. In a study that examines the effects of primary versus team nursing on quality of patient care, Gardner (1989) finds that primary nursing care provides higher quality care when compared to team nursing. Primary nursing is a system of delivery that requires more nurses. Team nursing has been a response to nursing shortages in the past and essentially decreases the number of nurses per patient and substitutes them with less skilled labor. Also, in a study done by the American Nurses Association (1997) they found nursing hours to be significant factor in producing better quality. Moreover, they use 1992 data for California hospitals, which this study will use (discussed in detail below). Therefore, nursing hours as a measure of quality agrees nicely with the notion that better quality in hospital care is obtained through using greater quantities of skilled labor that directly provide the care patients receive

Gertler and Waldman (from hereon referred to as G&W), on the other hand, used endogenous and unobserved quality in their study to examine the effects on nursing home cost. G&W treat quality as unobserved and endogenous in response to the Brautingham and Pauly (1986) study that found that ignoring quality could lead to biased results. Furthermore G&W develop a study whereby they assume quality is difficult if not impossible to measure. They include quality in the equation by using demand-related variables, which affect the demand curve, to explain quality variations. In summary, the G&W (1992) paper addresses quality and analyzes its effects on cost. Procedures used in their study can be used here. For example, G&W look at the cost elasticity of quality and make important policy conclusions from it. This study calculates the cost elasticity of quality and interprets the result.

Finally, all studies, except for Bays (1980) use the translog as the functional form. Mckay even criticizes other works for using Cobb-Douglas functions. This study will estimate a cost function using both functional forms, and compare the results. Furthermore, this study will demonstrate that the translog is appropriate over the Cobb-Douglas. Functional form is discussed in more detail in Section 3.

3. Empirical Methods

This section describes the empirical approach to this study. First, Section 3.1 will develop a model for hospital cost. Then Section 3.2 discusses functional form, and Section 3.3 specifies the cost function.

3.1 Model

This paper models the hospital as a multi-product firm which utilizes labor, capital, supplies, and size measured by the total number of hospital beds, to produce a certain level of output. The literature suggests that this study should model the hospital as a multi-product firm since more than one service is produced. Hospitals may generate output in the form of inpatient hospital care, outpatient surgery, emergency room services, etc. Given the multi-product nature of the hospital, a set of inputs, and a certain level of quality, the total cost function may be defined as:

$$C=f(Y', p', K, M, Z, Q),$$

where each variable is defined as follows. C is total hospital cost. Y' is a vector of outputs represented by: inpatient hospital care, the number of emergency room visits, and the total number of surgeries. The variable p' is a vector of input prices represented by: nurse wages, nursing aid wages, and the cost of supplies. K represents the capital stock. M is a variable measuring physician input in the production of hospital care, which is represented by the total number of admitting physicians.[4] The size variable Z, is the total

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[4] Bays (1979) indicates that mis-specification error can occur if physician input is not represented in the cost function.

number of licensed beds and Q represents quality, which is measured by two different variables: nursing hours divided by patient days or the risk adjusted mortality rate.[5] This cost function assumes that hospitals minimize total cost, given patients demand for hospital services, input prices, the capital stock, the number of admitting physicians, size, and a given level of quality.

3.2 Functional Form

The prevailing functional form observed in the literature review of hospital and nursing home cost functions is the translog. It rivals use of the Cobb-Douglas form popular in other cost function studies throughout the econometric literature. The primary reason cited in the literature for use of a flexible functional form (translog) is because the inherent restriction that the Cobb-Douglas imposes of unitary elasticity of substitution is not appropriate for the case of hospitals and nursing homes. Simply stated, this condition is likely not to be the case in the real world (Silberberg, 1990). The translog is a functional form where its derivation is a second-order Taylor Series expansion of the Cobb-Douglas. Thus, the Cobb-Douglas is a restricted translog where all the cross product terms and squares equal zero. The quadratic terms generated, which are specified in the next section, with the cross products and squares allow for elasticity of factor substitution to be unrestricted (Greene, 1993).

This paper will compare the results of the different functional forms and test for the significance of one versus the other using the *F*-test, which is a method of testing for the significance of the restricted (Cobb-Douglas) regression versus the unrestricted (translog) regression.

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[5] In the quality indicator, patient days represent the largest output of the hospital, inpatient-nursing care.

3. 3 Empirical Specification

A mulit-product Cobb-Douglas cost function is specified as:

$$\text{(1)} \quad \ln C = \alpha_0 + \Sigma_r \alpha_r \ln Y_r + \Sigma_i \beta_i \ln p_i + \delta_K \ln K + \delta_M \ln M + \delta_Z \ln Z + \delta_Q \ln Q + \Psi T + \varepsilon,$$

where outputs Y_r are indexed *r = patient days (D), the total number of emergency visits (E), the total number surgeries (U),* and inputs are indexed *i = nurse wage (N), nursing aid wage (A), cost of supplies (S).*[6] When estimating this equation, dummy variable *T* is added to the regression where 0 indicates a non-teaching facility, and 1 indicates a teaching facility. Finally, ε represents the error term. The regressions for the Cobb-Douglas function provide coefficients (α, β, and δ), with the exception of the teaching variable, that are elasticities.

The translog, is specified as follows:

$$\begin{aligned} \text{(2)} \quad \ln C = {} & \alpha_0 + \Sigma_r \alpha_r \ln Y_r + \tfrac{1}{2} \Sigma_r \Sigma_s \alpha_{rs} \ln Y_r \ln Y_s + \Sigma_i \beta_i \ln p_i \\ & + \tfrac{1}{2} \Sigma_i \Sigma_j \beta_{ij} \ln p_i \ln p_j + \delta_K \ln K + \tfrac{1}{2}\delta_{KK} (\ln K)^2 + \delta_M \ln M \\ & + \tfrac{1}{2}\delta_{MM} (\ln M)^2 + \delta_Z \ln Z + \tfrac{1}{2}\delta_{ZZ} (\ln Z)^2 + \delta_Q \ln Q + \delta_{QQ} (\ln Q)^2 \\ & + \Sigma_r \Sigma_i \delta_{ri} \ln Y_r \ln p_i + \Sigma_r \delta_{rK} \ln Y_r \ln K + \Sigma_r \delta_{rM} \ln Y_r \ln M \\ & + \Sigma_r \delta_{rZ} \ln Y_r \ln Z + \Sigma_r \delta_{rQ} \ln Y_r \ln Q + \Sigma_j \delta_{iK} \ln p_i \ln K \\ & + \Sigma_i \delta_{iM} \ln p_i \ln M + \Sigma_i \delta_{iZ} \ln p_i \ln Z + \Sigma_i \delta_{iQ} \ln p_i \ln Q \\ & + \delta_{KM} \ln K \ln M + \delta_{KZ} \ln K \ln Z + \delta_{KQ} \ln K \ln Q \end{aligned}$$

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[6] The summation is shorthand for listing the addition of each variable. For example, $\Sigma_r \alpha_r \ln Y_r = \alpha_{patient\ days} \ln Y_{patient\ days} + \alpha_{emergency\ visits} \ln Y_{emergency\ visits} + \dots$.

$$+ \delta_{MZ} \ln M \ln Z + \delta_{MQ} \ln M \ln Q + \delta_{ZQ} \ln Z \ln Q + \Psi T + \varepsilon,$$

where outputs are indexed r,s = *patient days (D), the total number of emergency visits (E), the total number of surgeries (U),* and inputs are indexed i, j = *nurse wage (N), nursing aid wage (A), cost of supplies (S).* The parameters to be estimated are represented by the Greek letters: α, β, δ, and Ψ. Each subscript indicates the parameter is the coefficient for the variable itself, for example δ_Z is the coefficient estimated for the size variable. A parameter with two letters in the subscript indicates it is a coefficient for a cross-product term, such as δ_{KA} is the coefficient of the cross product of capital and the number admitting physicians, or, represents the square. Unlike the Cobb-Douglas, the elasticities must be computed from the translog's results.[7] For example, the cost elasticity of output is equal to $\Sigma_r \partial \ln C / \partial \ln Y_r$ (Greene, 1993). Once the partial derivative of cost with respect to output is computed, the mean values of the variables are used to calculate a value for the cost elasticity of output.

This paper will also determine if the estimates for the functions specified exhibit increasing returns to scale i.e., larger quantities of the firm's output are produced at a lower average cost than are smaller quantities of output. Scale economies are measured by:

$$(3) \qquad SCE = 1 - \Sigma_r \vartheta C / \vartheta Y_r \,,$$

where $SCE > 0$ for increasing returns to scale, $SCE = 0$ for constant returns to scale, and $SCE < 0$ for decreasing returns to scale (Mckay, 1988).[8]

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[7] Furthermore, the elasticities of substitution are simple to compute once the parameters are estimated.

[8] In the case of the Cobb-Douglas function, the partial derivative of cost with respect to total output reduces simply to the sum of the coefficients on each output.

4. Data

The data used in this study are from annual observations for 583 hospitals in the state of California for the year 1992 collected by the Office of Statewide Health Planning and Development. Specialty hospitals, e.g. psychiatric, long-term care, etc., are eliminated from this data set. The resulting data set consists of statistics for 184 short-term, general hospitals that provide emergency room services. Table 1 provides descriptive statistics for the variables used in this study.

Table 1.

Descriptive Statistics

Variable	Mean	Standard Deviation
Total Cost ($)	73, 095, 112	74, 068, 838
Emergency Room Visits	24,652	16, 277
Number of Surgeries	7,444	17, 125
Nursing Aid Wage ($/hour)	9.923	1.713
Registered Nurse Wage ($/hour)	24.23	3.078
Supplies ($)	11, 582, 549	11, 948, 208
Building and Equipment ($)	68, 253, 759	72, 348, 181
No. of Admitting Physicians	403	1390
Licensed Beds	39, 279	170.4
Nursing Hours per patient day	6.562	2.821
Risk Adjusted Mortality Rate	15.190	4.434

Total operating cost, including labor, supplies, benefits, professional fees, purchased services, and other direct expenses, is used as the measure for total hospital cost (C). Wages are measured by average hourly wages for nurses (p_N) and nursing aids (p_A). Total supply costs represent the supply variable (S), and a total book value for building and equipment divided by the bed size of the facility is the capital variable (K). The data for the output variables include: total patient census days (Y_D), which measures inpatient output, total number of surgeries performed (Y_S), and the number of emergency room visits (Y_E). The data used for the admitting physician variable (M) is total number of affiliated physicians for each hospital and licensed bed size of the facility is the size variable (Z). The two quality variables include total nursing hours divided by patient days ($Q=NH/Y_D$), and a risk adjusted mortality rate (from hereon abbreviated *RAM*). Lastly, if the hospital has an approved residency program, it is considered a teaching hospital with the dummy variable taking on a value of 1, otherwise it is 0.

5. Empirical Results

The following section examines the results of the regressions for the equations specified in section 3.3. The section is organized as follows. The first section will discuss the results for the Cobb-Douglas. Section 5.2 will examine the results of the translog. Section 5.3 will test the appropriateness of the Cobb-Douglas versus the translog, and Section 5.4 discusses a test for Heteroscedasticity in the data.

5.1 Regression Results for the Cobb-Douglas Specification

Table 2 shows the results for separate Cobb-Douglas regressions using nursing hours per patient day as the quality variable in second and third columns, and risk adjusted mortality rate in the fourth and fifth.[9] Reviewing the signs, they are all as expected with the exception of surgery whose negative coefficient in both regressions is a surprise, however, its' *t*-value shows it is not significant.

In the first regression our quality variable $Q=NH/Y_D$, is significant. In the second, where *RAM* represents quality, it is not significant so our analysis will focus only on the results of the first regression.

The estimate for the coefficient on quality of 0.13 may be interpreted to suggest a 10 percent increase in quality, holding all else constant, will cause a 1.3 percent increase in total cost. This result is consistent with the discussion in Section 2 that quality is expected to positively affect cost. Based on this result, a policy designed to improve quality will

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[9] All regressions are performed with MINTAB version 12.2 statistical software. Appendix A provides the output of the regressions using the Cobb-Douglas and Appendix B contains the output for the translog regressions.

increase total cost. Furthermore, this finding is consistent with the findings of Moskowitz (1994), Gardner (1989), and American Nurse Association (1997), which suggest cost cutting strategies in the form of reducing nurse labor deteriorates quality. Although their models do not involve cost functions, their studies are done as a result of the predominance of cost cutting experienced by the hospital industry. In turn, this paper's regression results discussed so far have estimated what economic effect quality, as measured by nursing hours divided by patient days, has on cost.

Finally, the results for the regression using $Q=NH/Y_D$ demonstrate increasing returns to scale in the production of hospital care. The value for *SCE* is 0.27, and is computed using equation (3).[10] This result would suggest that as output increases, cost is increasing at a decreasing rate. For example, if total output were to increase by 10 percent, average cost would decline by about 2.6 percent.[11]

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[10] $\alpha_{surgeries}$ is dropped from the calculation of *SCE* since it was not significant and has a very low value.

[11] G&H (1992) use a similar example where they compute *SCE* in the quality exogenous case to be .061 and state that this implies a doubling of patients would lead to a 6 percent reduction in average cost.

Table 2.

Regression results for the Cobb-Douglas functional form

Variable	Parameter	Estimate	*t*-value	Estimate	*t*-value
Constant	α_0	3.8035 (0.4379)	8.69	3.5051 (0.4738)	7.40
Patient Days	α_D	0.64910* (0.04486)	14.47	0.59863* (0.04360)	13.73
Emergency	α_E	0.08523* (0.02699)	3.16	0.10158* (0.02752)	3.69
Surgeries	α_S	-0.00202 (0.01895)	-0.11	-0.00320 (0.01961)	-0.16
Aid Wage	β_A	0.18511* (0.08015)	2.31	0.19705* (0.07976)	2.47
Nurse Wage	β_N	0.2156* (0.1127)	1.91**	0.2306* (0.1155)	2.00
Supplies	β_S	0.50240* (0.04439)	11.32	0.56523* (0.04194)	13.48
Capital	δ_K	0.07407* (0.02513)	2.95	0.08550* (0.02584)	3.31
Admitting Physicians	δ_M	0.01225 (0.01498)	0.82	0.01419 (0.04252)	0.92
Size	δ_Z	0.25359* (0.04393)	5.77	0.30554* (0.03477)	7.19
$Q=NH/Y_D$	δ_Q	0.12714* (0.03785)	3.36	--	--
$Q=RAM$	δ_Q	--	--	0.01588 (0.03477)	0.46
Teach	Ψ	0.01642 (0.02180)	0.75	0.02113 (0.02246)	0.94
		$R^2=0.976$ $SSE=3.406$		$R^2=0.975$ $SSE=3.639$	

* Significant at 5 percent level

** Significant at 10 percent level

5.2 Regression Results for the Translog Specification

5.2.1 Translog Results for Quality Equal to Nursing Hours Divided by Patient Days

Table 3 displays the regression results for the translog estimating the cost function where quality is equal to nursing hours divided by patient days ($Q=NH/Y_D$). There are a number of parameters estimated and as is usually the case, there are a number of coefficients with low *t*-values. The same results are exhibited in the literature for C&H (1983) where a number of estimates have low *t*-values. Mckay (1988) does not address *t*-values at all. Since by its very definition the translog increases the number of parameters to be estimated by adding cross-products and squares of all the variables, it also increases the likelihood of inducing problems such as those seen with multicolinearity. With this in mind, this study will focus more on the results of the *F*-tests to test significance of including the quality variables in the regressions for the translog. For the problem this paper addresses, *what effect does quality have on cost*, it will be demonstrated that the quality variables are significant in the translog regression based on the *F*-test.

The parameter estimates of the translog do not reflect elasticities. For example, the cost elasticity of quality must be computed by taking the partial derivative of cost with respect to quality in equation (2). The resulting elasticity, as shown in Table 6, is 0.26. This implies a 10 percent change in quality, holding all else constant, results in a 2.6 percent change in costs. This result is as expected, since quality has a positive relationship with cost. However, this value calculated from the translog estimates is higher than the estimate obtained from the results the Cobb-Douglas, which may suggest that allowing for unrestricted elasticity of substitution with the translog is the reason for the difference.

In testing whether all the parameters associated with quality in the translog function are significant, or not equal to zero, the F-test rejects the null hypothesis that $\delta_{rQ} = \delta_Q = \delta_{QQ} = \Sigma_i \delta_{iQ} = \delta_{KQ} = \delta_{MQ} = \delta_{ZQ} = 0$, where r equals each output (patient days, emergency visits, and total number of surgeries) and i equals each factor-input (nurse wage, nursing aid wage, and supplies).[12] Therefore, these parameter estimates are significant in explaining quality. The same conclusion is made as in the previous section that discusses the results of the Cobb-Douglas functional form: policies that improve quality will lead to an increase in total cost. Moreover, since our quality variable includes nursing hours, decreasing the number of nurses will lower quality as well as costs.

The estimate for scale economies, displayed in Table 6 of 0.19, is very close to the calculation of 0.14 that C&H (1983) estimate and suggests that for a 10 percent change in total output, holding all else constant, average cost declines by about 2 percent. Again, as in the Cobb-Douglas, this result implies the average hospital experiences increasing returns to scale, which is consistent with the findings in other hospital cost function studies.[13]

Finally, a high value for R^2 (Table 3) shows the data fit the regression well, which is consistent with the results obtained in the Cobb-Douglas regressions.

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[12] The F-value is calculated using the following formula:

$$F_{(J,\, n\text{-}K)} = \frac{\text{(SSR of restricted regression-SSR of unrestricted regression)}/J}{\text{(SSR of unrestricted)}/(n\text{-}K)}$$

where J = number of restrictions (number of estimated parameters in unrestricted regression minus number of estimated parameters in the restricted), n equals the sample size, K equals the number of estimated parameters in the unrestricted regression, and SSR is the residual sum of squares.

[13] *SCE* is calculated using mean values of the data.

5.2.2 Translog Results for Quality Equal to Risk Adjusted Mortality Rate

Table 4 displays the regression results where quality equals *RAM*. The discussion in the previous section regarding the number of regressors and low *t*-values, etc. applies to this case as well. However, in this regression there are more significant variables than in the previous regression for the translog. Also, as with all the previous regressions there is a high value for R^2.

The quality indicator, *RAM*, is computed to have an elasticity of 0.031. This is considerably smaller than the results obtained above. In this case a 10 percent change in quality would lead to a 0.3 percent change in cost. Based on the *F*-test with 95 percent confidence the null hypothesis that the coefficients for quality jointly do not have a significant impact on cost is rejected (see Table 5). However, with 99 percent confidence, the null is not rejected and this result may be possibly due to the risk adjusted mortality rate, being a poor proxy for quality, since it only measures risk adjusted mortality rates for heart attack patients (see Section 1.1 for discussion on *RAM*).

The estimate for *SCE* is 0.4 implying a 10 percent change in total output would lead to a 4 percent decrease in average cost. This result also implies increasing returns to scale although its value is higher that the other estimates in this study.

Table 3.

Translog Regression results where *Q* = nursing hours divided by patient days

Parameter	Coefficient	Standard deviation	*t*-value
α_0	18.91	15.56	1.22
α_D	0.590	2.248	0.26
α_E	-0.875	1.439	-0.61
α_U	0.3461	0.9948	0.35
β_A	-3.382	3.243	-1.04
β_N	-3.780	6.452	-0.59
β_S	0.063	2.286	0.03
δ_K	-0.453	1.351	-0.34
δ_M	0.2362	0.7936	0.30
δ_Z	1.022	2.004	0.51
δ_Q	0.699	2.233	0.31
α_{DD}	0.0057	0.2981	0.02
α_{EE}	0.08908	0.09073	0.98
α_{UU}	-0.00533	0.02459	-0.22
α_{DE}	0.0547	0.2602	0.21
α_{DU}	0.001022	0.004274	0.24
α_{EU}	-0.07958	0.09333	-0.85
β_{AA}	-1.7613**	0.9155	-1.92
β_{NN}	1.812	2.075	0.87
δ_{KK}	0.22090*	0.07448	2.97
β_{SS}	-0.0361	0.2899	-0.12
δ_{MM}	0.01573	0.03279	0.48
δ_{ZZ}	0.1779	0.3436	0.52
δ_{QQ}	0.0261	0.1451	0.18
β_{AN}	1.895	2.289	0.83
δ_{AK}	0.2680	0.2500	1.07
β_{AS}	0.8719	0.8446	1.03
β_{NS}	-1.305	1.090	-1.2
δ_{NK}	-0.3775	0.3694	-1.02
δ_{KS}	-0.0200	0.1432	-0.14
δ_{DA}	0.1411	0.5287	0.78
δ_{DN}	0.1841	0.6407	0.29
δ_{DK}	-0.1388	0.1635	-0.85
δ_{DS}	-0.0687	0.2252	-0.31
δ_{EK}	-0.828	0.1083	-0.76
δ_{UK}	0.01933	0.06048	0.32

Table 3. Continued

δ_{EA}	-0.3816	0.2836	-1.35
δ_{EN}	0.4103	0.3780	1.09
δ_{ES}	0.3028*	0.1317	2.3
δ_{UA}	-0.2464	0.2008	-1.23
δ_{UN}	0.2644	0.2318	1.14
δ_{US}	-0.0605	0.1194	-0.51
δ_{ZA}	0.1749	0.4715	0.37
δ_{ZN}	-1.1515*	0.5853	-1.97
δ_{ZK}	0.2353	0.1609	1.46
δ_{ZS}	0.0787	0.2021	0.39
δ_{QA}	-0.3197	0.4705	-0.68
δ_{QN}	1.1944*	0.5370	2.22
δ_{QK}	-0.3081**	0.1613	-1.91
δ_{QS}	0.2174	0.2499	0.87
δ_{DZ}	0.0107	0.3129	0.03
δ_{DQ}	0.1501	0.2186	0.69
δ_{UQ}	-0.0047	0.1172	-0.04
δ_{ZQ}	-0.1363	0.2432	-0.56
δ_{EQ}	-0.2197	0.1578	-1.39
δ_{EZ}	-0.1307	0.1389	-0.94
δ_{ZS}	-0.03702	0.05061	-0.73
δ_{DM}	0.00793	0.08300	0.1
δ_{EM}	0.01934	0.04522	0.43
δ_{UM}	0.02201	0.04592	0.48
δ_{AM}	0.0026	0.1386	0.02
δ_{NM}	0.0455	0.1895	0.24
δ_{SM}	-0.13266	0.08211	-1.62
δ_{KM}	-0.01921	0.04648	-0.41
δ_{AM}	-0.02222	0.07167	-0.31
δ_{QM}	0.08561	0.09031	0.95
ψ	0.02116	0.02014	1.05
	R^2 = 0.989	SSR = 1.5866	

* Significant at 5 percent level

** Significant at 10 percent level

Table 4.

Translog Regression results where Q = RAM

Parameter	Coefficient	Standard deviation	*t*-value
α_0	0.49	20.13	0.02
α_{D}	-3.901**	2.138	-1.82
α_{E}	0.009	1.680	0.01
α_{U}	0.158	1.039	0.15
β_{A}	-1.790	4.289	-0.42
β_{N}	-3.087	6.521	-0.47
β_{S}	-3.240	2.210	-1.47
δ_{K}	4.989*	1.573	3.17
δ_{M}	-0.2896	0.9517	-0.30
δ_{Z}	5.332*	2.281	2.34
δ_{Q}	0.871	2.354	0.37
α_{DD}	0.1228	0.2965	0.41
α_{EE}	0.0608	0.1164	0.52
α_{UU}	-0.03021	0.02705	-1.12
α_{DE}	0.4000	0.2847	1.41
α_{DU}	-0.000916	0.004969	-0.18
α_{EU}	-0.2323*	0.1177	-1.97
β_{AA}	-1.7012*	0.7846	-2.17
β_{NN}	-0.953	2.039	-0.47
δ_{KK}	0.06693	0.08122	0.82
β_{SS}	0.1421	0.2689	0.53
δ_{MM}	0.02371	0.03334	0.71
δ_{ZZ}	0.1568	0.3067	0.51
δ_{QQ}	-0.1479	0.1422	-1.04
β_{AN}	4.168**	2.382	1.75
δ_{AK}	.0983	0.2580	0.38
β_{AS}	1.2607	0.9826	1.28
β_{NS}	0.439	1.101	0.4
δ_{NK}	-0.5900	0.3918	-1.51
δ_{KS}	-0.2587	0.1612	-1.60
δ_{DA}	1.2750*	0.4590	2.78
δ_{DN}	-0.5173	0.5995	-0.86
δ_{DK}	-0.0364	0.1647	-0.22
δ_{DS}	0.0797	0.2512	0.32
δ_{EK}	-0.2505*	0.1154	-2.17

Table 4. Continued

δ_{UK}	0.16242*	0.07284	2.23
δ_{EA}	-0.8062*	0.3006	-2.68
δ_{EN}	0.7338**	0.3986	1.84
δ_{ES}	0.3691*	0.1349	2.74
δ_{UA}	-0.4903*	0.2235	-2.19
δ_{UN}	0.2305	0.2598	0.89
δ_{US}	-0.0800	0.1002	-0.8
δ_{ZA}	-0.7004**	0.3976	-1.76
δ_{ZN}	-0.1608	0.5719	-0.28
δ_{ZK}	-0.0254	0.1575	-0.16
δ_{ZS}	0.0786	0.2349	0.33
δ_{QA}	-1.1747*	0.4201	-2.8
δ_{QN}	1.6059*	0.6035	2.66
δ_{QK}	-0.4127*	0.1452	-2.84
δ_{QS}	0.1281	0.1675	0.77
δ_{DZ}	0.0545	0.2926	0.19
δ_{DQ}	0.0530	0.1557	0.34
δ_{UQ}	-0.0077	0.1201	-0.06
δ_{ZQ}	-0.1050	0.1738	-0.6
δ_{EQ}	0.1856**	0.1085	1.71
δ_{EZ}	-0.3183*	0.1493	-2.13
δ_{ZS}	-0.09405	0.05719	-1.64
δ_{DM}	-0.08880	0.07370	-1.20
δ_{EM}	0.03261	0.05012	0.65
δ_{UM}	0.11466*	0.04928	2.33
δ_{AM}	0.0723	0.1534	0.47
δ_{NM}	0.0804	0.1937	0.42
δ_{SM}	-0.11251	0.07903	-1.42
δ_{KM}	0.02471	0.04691	0.53
δ_{AM}	-0.03202	0.06718	-0.48
δ_{QM}	-0.05501	0.07373	-0.75
ψ	0.04126**	0.02307	1.79
	$R^2 = 0.986$	$SSR = 2.0396$	

* Significant at 5 percent level
** Significant at 10 percent level

Table 5.

F-Tests for Cobb-Douglas *vs.* Translog
and
Translog using $Q=NH/Y_D$ *vs.* $Q=RAM$
with 95 percent confidence (unless otherwise noted)

Null Hypothesis	Calculated F statistic	5 % Critical Value	Outcome
H_0: Cobb Douglas is appropriate for $Q = NH/Y_D$ *vs.* Translog	2.46	1.48*	Reject H_0. Translog is appropriate
H_0: Cobb Douglas is appropriate for $Q = RAM$ *vs.* Translog	1.68	1.48*	Reject H_0. Translog is appropriate
H_0: Restricted regression is appropriate *vs.* Translog with $Q = NH/Y_D$	5.59	1.93**	Reject H_0. Coefficients for quality significant in translog regression.
H_0: Restricted regression is appropriate *vs.* Translog with $Q =$ RAM	1.97	1.93**$^{+}$	Reject H_0. Coefficients for quality are significant in translog regression.

* Actual degrees of freedom $F_{(55,\ 118)}$ rounded to $F_{(50,\ 100)}$
** Actual degrees of freedom $F_{(11,\ 118)}$ rounded to $F_{(10,\ 100)}$
$^{+}$ Not significant with 99 percent confidence level
Note: Degrees of freedom rounded to values listed in standard F-tables. In either case, values were rounded to nearest figure, which gave a higher value for F.

5.3 The Cobb-Douglas versus the Translog

In this section, results are presented for testing the significance of the regressions using the Cobb-Douglas function versus the translog. In other words, if all the additional parameters in the translog not included in the Cobb-Douglas function equal zero.

The literature varies in whether or not the researchers test for the appropriateness of the translog. While G&W (1992) make no mention of testing the appropriateness of the translog, Mckay argues its use based on relevant theory and the need to impose homogeneity on the input prices. C&H (1983) in defense of the translog state, "…a multi-product hospital is inconsistent with a Cobb-Douglas specification for a proprietory hospital because this specification implies complete specialization." Furthermore, they conduct a likelihood ratio test and reject the Cobb-Douglas at the 0.05 level. Since this paper uses least squares to estimate the functions, the appropriate method for testing whether:

$$\begin{aligned}&\Sigma_r\, \Sigma_s\, \alpha_{rs} = \Sigma_i\, \Sigma_j\, \beta_{ij} = \delta_{KK} = \delta_{MM} = \delta_{ZZ} = \delta_{QQ} = \Sigma_r\, \Sigma_i\, \delta_{ri}\\ &= \Sigma_r\, \delta_{rK} = \Sigma_r\, \delta_{rM} = \Sigma_r\, \delta_{rZ} = \Sigma_r\, \delta_{rQ} = \Sigma_j\, \delta_{iK} = \Sigma_i\, \delta_{iM} = \Sigma_i\, \delta_{iZ}\\ &= \Sigma_i\, \delta_{iQ} = \delta_{KM} = \delta_{KZ} = \delta_{KQ} = \delta_{MZ} = \delta_{MQ} = \delta_{ZQ} = 0,\end{aligned}$$

is the *F*-test.[14] Greene (1993) explains that when testing a set of linear restrictions, one is concerned with the "loss of fit" imposed by the restrictions and the appropriate tool is the *F*-test. Furthermore, Berndt and Christensen (1973) use the *F*-test in their pioneering study of the translog to test for significance across restricted and unrestricted equations.

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[14] If we were to use maximum likelihood estimation, a log-likelihood value would be used.

Table 5 displays the results of *F*-tests conducted comparing the Cobb-Douglas to the translog. In both cases, the Cobb-Douglas is rejected. It may therefore be concluded that the translog better represents the model for hospital cost.

Table 6.

Calculation of Elasticities and *SCE* from Translog Regressions

Elasticity *	Elasticity Value	*SCE***
Cost Elasticity of quality where $Q=NH/Y_D$	0.26	-----
Cost elasticity of quality where $Q=RAM$	0.031	-----
Cost elasticity of output where $Q= NH/Y_D$	0.81	*SCE* = 1-0.81 = 0.19
Cost elasticity of output where $Q=RAM$	0.60	*SCE* = 1 – 0.60 = 0.4

* The cost elasticity of output with respect to quality or output is calculated by taking the partial derivative of total cost with respect to quality or output. In the case of output, the partials of the three variables are summed.

** *SCE* is calculated using equation (4).

5.4 Test for Heteroscedasticity

Heteroscedasticity can occur in studies using panel data since variance tends not to be constant. For example, even after accounting for the difference in hospital sizes, we expect to see greater variations in costs with larger hospitals than those seen in smaller hospitals.

This study uses the Goldfeld-Quandt test to detect Heteroscedasticity.[15] This test is done by first sorting the data set in some order such as smallest to largest hospital (number of beds determines size) and then dividing the data in half. Then observations are dropped from the data set; Greene (1993) suggests no more than a third, but that the number is really arbitrary. This case dropped as many as possible for a total of 24.[16] Finally, to conduct the test, regressions are run for each dataset and the results are used to calculate an *F*-statistic (see Appendix C. for regression results).[17] Then an *F*-test is used to accept or reject the null hypothesis of Heteroscedasticity. The results show at the 95 percent level that the null is rejected.

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[15] Greene (1993) provides different tests that may be performed. This study used his procedure for the Goldfeld–Quandt test.

[16] If more than 24 observations are dropped, statistical software would generates an error message specifiying too few observations to produce regression results.

[17] The results listed in Appendix C are only for the test on the data using the translog regression where quality is equal to nursing hours divided by patient days, since the test using the other regression gives the same result.

6. Conclusions

Hospitals are faced with many challenges in cutting costs while providing the same level of service. This study shows that quality is a significant factor in determining the cost of producing hospital care. Discussed in previous sections, measuring quality is difficult especially in the case of hospitals. Many different measures may be suggested, however, they are difficult to obtain. This study uses two quality variables and studies what impact each has on hospital costs. Regressions are run separately for each variable using two different functional forms: the Cobb-Douglas and the translog. The estimates for the quality variables in all regressions except for the case where quality is measured by the risk adjusted mortality rate and is used in the Cobb-Douglas, are significant and have a positive relationship with cost. Therefore, policies designed to improve quality will increase hospital cost.

The results of this study suggest that for the average hospital, there are economies of scale in the production of healthcare. This result is consistent with the findings throughout the literature.

In testing for the appropriate functional form, based on an *F*-test, the translog is appropriate over the Cobb-Douglas. Similar results are also found in the literature and suggest that the assumption of unitary elasticity of substitution inherent in the Cobb-Douglas function is not the case for hospitals.

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Appendix A

MINITAB Regression Output for Cobb-Douglas Functional Form

Regression Analysis: Regression for Cobb-Douglas where Q=NH/Y

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The regression equation is
COST = 3.80 + 0.649 DAYS + 0.0852 ER – 0.0020 SURG + 0.185 AW + 0.216 NW
           + 0.502 SUPP + 0.0741 CAP + 0.0123 ADM + 0.254 SIZE + 0.127
NH
           + 0.0164 TEACH

Predictor        Coef       StDev          T        P
Constant       3.8035      0.4379       8.69    0.000
DAYS          0.64910     0.04486      14.47    0.000
ER            0.08523     0.02699       3.16    0.002
SURG         -0.00202     0.01895      -0.11    0.915
AW            0.18511     0.08015       2.31    0.022
NW             0.2156      0.1127       1.91    0.057
SUPP          0.50240     0.04439      11.32    0.000
CAP           0.07407     0.02513       2.95    0.004
ADM           0.01225     0.01498       0.82    0.414
SIZE          0.25359     0.04393       5.77    0.000
NH            0.12714     0.03785       3.36    0.001
TEACH         0.01642     0.02180       0.75    0.452

S = 0.1407      R-Sq = 97.6%     R-Sq(adj) = 97.5%

Analysis of Variance

Source           DF          SS          MS         F        P
Regression       11     141.192      12.836    648.20    0.000
Residual Error  172       3.406       0.020
Total           183     144.597


Unusual Observations
Obs       DAYS       COST         Fit   StDev Fit    Residual    St Resid
  6        9.9    17.1866     16.6502      0.0934      0.5365      5.10RX
 56       12.5    20.1496     19.8293      0.0381      0.3203      2.36R
 60        9.9    18.1313     17.2898      0.0339      0.8415      6.16R
 66        7.9    16.4602     15.9174      0.0524      0.5428      4.16R
 81       10.4    17.9118     17.5910      0.0384      0.3208      2.37R
104        9.8    17.3408     17.0196      0.0621      0.3212      2.54R
107       10.2    17.4740     17.4419      0.0821      0.0321      0.28 X
135        9.4    16.0461     16.3746      0.0454     -0.3285     -2.47R
140       10.7    17.8041     18.0822      0.0410     -0.2781     -2.07R
177       10.8    17.9484     18.1191      0.0652     -0.1707     -1.37 X

R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.
```

Current worksheet: TLREGRESSDATAMORTmod.xls

Regression Analysis: Regression for Cobb-Douglas where Q=Risk adjusted mortality rate

```
The regression equation is
COST = 3.51 + 0.599 DAYS + 0.102 ER – 0.0032 SURG + 0.197 AW + 0.231 NW
           + 0.565 SUPP + 0.0855 CAP + 0.0142 ADM + 0.306 SIZE + 0.0159
MORT
           + 0.0211 TEACH

Predictor        Coef       StDev          T        P
Constant       3.5051      0.4738       7.40    0.000
DAYS          0.59863     0.04360      13.73    0.000
ER            0.10158     0.02752       3.69    0.000
SURG         -0.00320     0.01961      -0.16    0.870
AW            0.19705     0.07976       2.47    0.014
NW             0.2306      0.1155       2.00    0.047
SUPP          0.56523     0.04194      13.48    0.000
CAP           0.08550     0.02584       3.31    0.001
ADM           0.01419     0.01547       0.92    0.361
SIZE          0.30554     0.04252       7.19    0.000
MORT          0.01588     0.03477       0.46    0.648
TEACH         0.02113     0.02246       0.94    0.348

S = 0.1455      R-Sq = 97.5%     R-Sq(adj) = 97.3%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        11     140.958      12.814    605.63    0.000
Residual Error   172       3.639       0.021
Total            183     144.597

Unusual Observations
Obs       DAYS       COST         Fit   StDev Fit    Residual    St Resid
 56       12.5    20.1496     19.8496      0.0385      0.3000        2.14R
 60        9.9    18.1313     17.2761      0.0352      0.8552        6.06R
 66        7.9    16.4602     15.8240      0.0462      0.6362        4.61R
 81       10.4    17.9118     17.6237      0.0395      0.2881        2.06R
 98       10.9    19.1351     18.8420      0.0360      0.2931        2.08R
104        9.8    17.3408     17.0337      0.0640      0.3071        2.35R
107       10.2    17.4740     17.4073      0.0845      0.0668        0.56 X
135        9.4    16.0461     16.3930      0.0474     -0.3469       -2.52R
140       10.7    17.8041     18.1009      0.0420     -0.2969       -2.13R
157        9.7    17.1242     17.2694      0.0758     -0.1452       -1.17 X
177       10.8    17.9484     18.1165      0.0674     -0.1681       -1.30 X
R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.
```

Appendix B

MINITAB Regression Output for Translog Functional Form

Current worksheet: TLREGRESSDATAmod.xls

Regression Analysis: Regression for translog where Q=NH/Y

```
The regression equation is
COST = 18.9 + 0.59 DAYS - 0.88 ER + 0.346 SURG - 3.38 AW - 3.78 NW +
0.06 SUPP
           - 0.45 CAP + 0.236 ADM + 1.02 SIZE + 0.70 NH + 0.006
DAYSXDAYS
           + 0.0891 ERXER - 0.0053 SURGXSURG + 0.055 DAYSXER
           + 0.00102 DAYSXSURG - 0.0796 ERXSURG - 1.76 AWXAW + 1.81
NWXNW
           + 0.221 CAPXCAP - 0.036 SUPPXSUPP + 0.0157 ADMXADM
           + 0.178 SIZEXSIZE + 0.026 NHXNH + 1.90 AWXNW + 0.268 AWXCAP
           + 0.872 AWXSUPP - 1.31 NWXSUPP - 0.377 NWXCAP - 0.020
CAPXSUPP
           + 0.414 DAYSXAW + 0.184 DAYSXNW - 0.139 DAYSXCAP - 0.069
DAYSXSUPP
           - 0.083 ERXCAP + 0.0193 SURGXCAP - 0.382 ERXAW + 0.410 ERXNW
           + 0.303 ERXSUPP - 0.246 SURGXAW + 0.264 SURGXNW - 0.060
SURGXSUPP
           + 0.175 SIZEXAW - 1.15 SIZEXNW + 0.235 SIZEXCAP + 0.079
SIZEXSUPP
           - 0.320 NHXAW + 1.19 NHXNW - 0.308 NHXCAP + 0.217 NHXSUPP
           + 0.011 DAYSXSIZE + 0.150 DAYSXNH - 0.005 SURGXNH - 0.136
SIZEXNH
           - 0.220 ERXNH - 0.131 ERXSIZE - 0.0370 SURGXSIZE + 0.0079
DAYSXADM
           + 0.0193 ERXADM + 0.0220 SURGXADM + 0.003 AWXADM + 0.046
NWXADM
           - 0.133 SUPPXADM - 0.0192 CAPXADM - 0.0222 SIZEXADM + 0.0856
NHXADM
           + 0.0212 TEACH

Predictor         Coef       StDev          T        P
Constant         18.91       15.56       1.22    0.227
DAYS             0.590       2.248       0.26    0.793
ER              -0.875       1.439      -0.61    0.544
SURG            0.3461      0.9948       0.35    0.729
AW              -3.382       3.243      -1.04    0.299
NW              -3.780       6.452      -0.59    0.559
SUPP             0.063       2.286       0.03    0.978
CAP             -0.453       1.351      -0.34    0.738
ADM             0.2362      0.7936       0.30    0.767
SIZE             1.022       2.004       0.51    0.611
NH               0.699       2.233       0.31    0.755
```

```
DAYSXDAY       0.0057      0.2981       0.02    0.985
ERXER         0.08908     0.09073       0.98    0.328
SURGXSUR     -0.00533     0.02459      -0.22    0.829
DAYSXER        0.0547      0.2602       0.21    0.834
DAYSXSUR     0.001022    0.004274       0.24    0.811
ERXSURG      -0.07958     0.09333      -0.85    0.396
AWXAW         -1.7613      0.9155      -1.92    0.057
NWXNW           1.812       2.075       0.87    0.384
CAPXCAP       0.22090     0.07448       2.97    0.004
SUPPXSUP      -0.0361      0.2899      -0.12    0.901
ADMXADM       0.01573     0.03279       0.48    0.632
SIZEXSIZ       0.1779      0.3436       0.52    0.606
NHXNH          0.0261      0.1451       0.18    0.858
AWXNW           1.895       2.289       0.83    0.409
AWXCAP         0.2680      0.2500       1.07    0.286
AWXSUPP        0.8719      0.8446       1.03    0.304
NWXSUPP        -1.305       1.090      -1.20    0.234
NWXCAP        -0.3775      0.3694      -1.02    0.309
CAPXSUPP      -0.0200      0.1432      -0.14    0.889
DAYSXAW        0.4144      0.5287       0.78    0.435
DAYSXNW        0.1841      0.6407       0.29    0.774
DAYSXCAP      -0.1388      0.1635      -0.85    0.398
DAYSXSUP      -0.0687      0.2252      -0.31    0.761
ERXCAP        -0.0828      0.1083      -0.76    0.446
SURGXCAP      0.01933     0.06048       0.32    0.750
ERXAW         -0.3816      0.2836      -1.35    0.181
ERXNW          0.4103      0.3780       1.09    0.280
ERXSUPP        0.3028      0.1317       2.30    0.023
SURGXAW       -0.2464      0.2008      -1.23    0.222
SURGXNW        0.2644      0.2318       1.14    0.256
SURGXSUP      -0.0605      0.1194      -0.51    0.613
SIZEXAW        0.1749      0.4715       0.37    0.711
SIZEXNW       -1.1515      0.5853      -1.97    0.052
SIZEXCAP       0.2353      0.1609       1.46    0.146
SIZEXSUP       0.0787      0.2021       0.39    0.698
NHXAW         -0.3197      0.4705      -0.68    0.498
NHXNW          1.1944      0.5370       2.22    0.028
NHXCAP        -0.3081      0.1613      -1.91    0.059
NHXSUPP        0.2174      0.2499       0.87    0.386
DAYSXSIZ       0.0107      0.3129       0.03    0.973
DAYSXNH        0.1501      0.2186       0.69    0.494
SURGXNH       -0.0047      0.1172      -0.04    0.968
SIZEXNH       -0.1363      0.2432      -0.56    0.576
ERXNH         -0.2197      0.1578      -1.39    0.166
ERXSIZE       -0.1307      0.1389      -0.94    0.349
SURGXSIZ     -0.03702     0.05061      -0.73    0.466
DAYSXADM      0.00793     0.08300       0.10    0.924
ERXADM        0.01934     0.04522       0.43    0.670
SURGXADM      0.02201     0.04592       0.48    0.633
AWXADM         0.0026      0.1386       0.02    0.985
NWXADM         0.0455      0.1895       0.24    0.811
SUPPXADM     -0.13266     0.08211      -1.62    0.109
CAPXADM      -0.01921     0.04648      -0.41    0.680
SIZEXADM     -0.02222     0.07167      -0.31    0.757
```

```
NHXADM        0.08561     0.09031       0.95    0.345
TEACH         0.02116     0.02014       1.05    0.296

S = 0.1165      R-Sq = 98.9%     R-Sq(adj) = 98.3%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        66    143.0109      2.1668    159.79    0.000
Residual Error   117      1.5866      0.0136
Total            183    144.5975


Unusual Observations
Obs       DAYS       COST        Fit  StdDev Fit   Residual    St Resid
  2       11.3    19.2688    19.0505      0.0664     0.2184        2.28R
 10        8.7    16.3762    16.1542      0.0711     0.2220        2.41R
 32        9.3    16.5309    16.7367      0.0885    -0.2059       -2.72R
 60        9.9    18.1313    17.5543      0.0755     0.5770        6.51R
 85        8.3    15.8041    15.9410      0.1024    -0.1370       -2.47R
 87        8.9    15.8746    16.0463      0.0867    -0.1717       -2.21R
104        9.8    17.3408    17.1896      0.0994     0.1512        2.49R
155       11.2    18.4682    18.7059      0.0482    -0.2377       -2.24R
159       10.2    17.6563    17.4572      0.0849     0.1991        2.50R

R denotes an observation with a large standardized residual
```

Current worksheet: TLREGRESSDATAMORTmod.xls

Regression Analysis: Regression for translog where Q=Risk adjusted mortality rate

```
The regression equation is
COST = 0.5 - 3.90 DAYS + 0.01 ER + 0.16 SURG - 1.79 AW - 3.09 NW - 3.24
SUPP
           + 4.99 CAP - 0.290 ADM + 5.33 SIZE + 0.87 MORT + 0.123
DAYSXDAYS
           + 0.061 ERXER - 0.0302 SURGXSURG + 0.400 DAYSXER
           - 0.00092 DAYSXSURG - 0.232 ERXSURG - 1.70 AWXAW - 0.95 NWXNW
           + 0.142 SUPPXSUPP + 0.0669 CAPXCAP + 0.0237 ADMXADM
           + 0.157 SIZEXSIZE - 0.148 MORTXMORT + 4.17 AWXNW + 0.098
AWXCAP
           + 1.26 AWXSUPP + 0.44 NWXSUPP - 0.590 NWXCAP - 0.259 CAPXSUPP
           + 1.28 DAYSXAW - 0.517 DAYSXNW - 0.036 DAYSXCAP + 0.080
DAYSXSUPP
           - 0.251 ERXCAP + 0.162 SURGXCAP - 0.806 ERXAW + 0.734 ERXNW
           + 0.369 ERXSUPP - 0.490 SURGXAW + 0.230 SURGXNW - 0.080
SURGXSUPP
           - 0.700 SIZEXAW - 0.161 SIZEXNW - 0.025 SIZEXCAP + 0.079
SIZEXSUPP
           - 1.17 MORTXAW + 1.61 MORTXNW - 0.413 MORTXCAP + 0.128
MORTXSUPP
```

```
           + 0.055 DAYSXSIZE + 0.053 DAYSXMORT - 0.008 SURGXMORT
           - 0.105 SIZEXMORT + 0.186 ERXMORT - 0.318 ERXSIZE
           - 0.0941 SURGXSIZE - 0.0888 DAYSXADM + 0.0326 ERXADM
           + 0.115 SURGXADM + 0.072 AWXADM + 0.080 NWXADM - 0.113
SUPPXADM
           + 0.0247 CAPXADM - 0.0320 SIZEXADM - 0.0550 MORTXADM + 0.0413
TEACH

Predictor         Coef        StDev          T         P
Constant          0.49        20.13       0.02     0.981
DAYS            -3.901        2.138      -1.82     0.071
ER               0.009        1.680       0.01     0.996
SURG             0.158        1.039       0.15     0.879
AW              -1.790        4.289      -0.42     0.677
NW              -3.087        6.521      -0.47     0.637
SUPP            -3.240        2.210      -1.47     0.145
CAP              4.989        1.573       3.17     0.002
ADM            -0.2896       0.9517      -0.30     0.761
SIZE             5.332        2.281       2.34     0.021
MORT             0.871        2.354       0.37     0.712
DAYSXDAY        0.1228       0.2965       0.41     0.680
ERXER           0.0608       0.1164       0.52     0.602
SURGXSUR      -0.03021      0.02705      -1.12     0.266
DAYSXER         0.4000       0.2847       1.41     0.163
DAYSXSUR     -0.000916     0.004969      -0.18     0.854
ERXSURG        -0.2323       0.1177      -1.97     0.051
AWXAW          -1.7012       0.7846      -2.17     0.032
NWXNW           -0.953        2.039      -0.47     0.641
SUPPXSUP        0.1421       0.2689       0.53     0.598
CAPXCAP        0.06693      0.08122       0.82     0.412
ADMXADM        0.02371      0.03334       0.71     0.478
SIZEXSIZ        0.1568       0.3067       0.51     0.610
MORTXMOR       -0.1479       0.1422      -1.04     0.300
AWXNW            4.168        2.382       1.75     0.083
AWXCAP          0.0983       0.2580       0.38     0.704
AWXSUPP         1.2607       0.9826       1.28     0.202
NWXSUPP          0.439        1.101       0.40     0.691
NWXCAP         -0.5900       0.3918      -1.51     0.135
CAPXSUPP       -0.2587       0.1612      -1.60     0.111
DAYSXAW         1.2750       0.4590       2.78     0.006
DAYSXNW        -0.5173       0.5995      -0.86     0.390
DAYSXCAP       -0.0364       0.1647      -0.22     0.825
DAYSXSUP        0.0797       0.2512       0.32     0.752
ERXCAP         -0.2505       0.1154      -2.17     0.032
SURGXCAP       0.16242      0.07284       2.23     0.028
ERXAW          -0.8062       0.3006      -2.68     0.008
ERXNW           0.7338       0.3986       1.84     0.068
ERXSUPP         0.3691       0.1349       2.74     0.007
SURGXAW        -0.4903       0.2235      -2.19     0.030
SURGXNW         0.2305       0.2598       0.89     0.377
SURGXSUP       -0.0800       0.1002      -0.80     0.426
SIZEXAW        -0.7004       0.3976      -1.76     0.081
SIZEXNW        -0.1608       0.5719      -0.28     0.779
SIZEXCAP       -0.0254       0.1575      -0.16     0.872
```

```
SIZEXSUP       0.0786      0.2349       0.33    0.739
MORTXAW       -1.1747      0.4201      -2.80    0.006
MORTXNW        1.6059      0.6035       2.66    0.009
MORTXCAP      -0.4127      0.1452      -2.84    0.005
MORTXSUP       0.1281      0.1675       0.77    0.446
DAYSXSIZ       0.0545      0.2926       0.19    0.853
DAYSXMOR       0.0530      0.1557       0.34    0.734
SURGXMOR      -0.0077      0.1201      -0.06    0.949
SIZEXMOR      -0.1050      0.1738      -0.60    0.547
ERXMORT        0.1856      0.1085       1.71    0.090
ERXSIZE       -0.3183      0.1493      -2.13    0.035
SURGXSIZ     -0.09405     0.05719      -1.64    0.103
DAYSXADM     -0.08880     0.07370      -1.20    0.231
ERXADM        0.03261     0.05012       0.65    0.517
SURGXADM      0.11466     0.04928       2.33    0.022
AWXADM         0.0723      0.1534       0.47    0.638
NWXADM         0.0804      0.1937       0.42    0.679
SUPPXADM     -0.11251     0.07903      -1.42    0.157
CAPXADM       0.02471     0.04691       0.53    0.599
SIZEXADM     -0.03202     0.06718      -0.48    0.635
MORTXADM     -0.05501     0.07373      -0.75    0.457
TEACH         0.04126     0.02307       1.79    0.076

S = 0.1320      R-Sq = 98.6%     R-Sq(adj) = 97.8%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        66    142.5579      2.1600    123.90    0.000
Residual Error   117      2.0396      0.0174
Total            183    144.5975


Unusual Observations
Obs       DAYS       COST         Fit   StDev Fit    Residual    St Resid
  2       11.3    19.2688     18.9727      0.0727      0.2961       2.69R
 32        9.3    16.5309     16.7347      0.1003     -0.2039      -2.37R
 57        8.9    17.4678     17.6079      0.1212     -0.1402      -2.67R
 60        9.9    18.1313     17.5998      0.0886      0.5316       5.43R
 66        7.9    16.4602     16.1485      0.1077      0.3117       4.08R
 72        9.1    16.6564     16.8261      0.1190     -0.1697      -2.97R
104        9.8    17.3408     17.2016      0.1136      0.1392       2.07R
118       11.3    17.8555     17.6481      0.0999      0.2074       2.40R
155       11.2    18.4682     18.7243      0.0669     -0.2561      -2.25R
174        9.2    16.4657     16.3120      0.1090      0.1537       2.06R

R denotes an observation with a large standardized residual
```

Regression Analysis: "Restricted" regression for translog with no quality variables.

```
The regression equation is
```

```
COST = 13.3 - 3.33 DAYS + 0.91 ER + 0.504 SURG - 3.27 AW - 0.94 NW -
2.94 SUPP
           + 1.73 CAP + 0.195 ADM + 3.76 SIZE + 0.230 DAYSXDAYS - 0.044
ERXER
           - 0.0163 SURGXSURG + 0.426 DAYSXER + 0.00249 DAYSXSURG
           - 0.087 ERXSURG - 2.00 AWXAW - 0.48 NWXNW + 0.233 SUPPXSUPP
           + 0.172 CAPXCAP + 0.0203 ADMXADM + 0.395 SIZEXSIZE + 3.79
AWXNW
           - 0.059 AWXCAP + 1.55 AWXSUPP - 0.46 NWXSUPP - 0.208 NWXCAP
           - 0.167 CAPXSUPP + 1.15 DAYSXAW - 0.701 DAYSXNW - 0.059
DAYSXCAP
           + 0.164 DAYSXSUPP - 0.263 ERXCAP + 0.0766 SURGXCAP - 0.733
ERXAW
           + 0.768 ERXNW + 0.330 ERXSUPP - 0.406 SURGXAW + 0.279 SURGXNW
           - 0.168 SURGXSUPP - 0.597 SIZEXAW - 0.135 SIZEXNW + 0.125
SIZEXCAP
           + 0.061 SIZEXSUPP - 0.144 DAYSXSIZE - 0.349 ERXSIZE
           - 0.0688 SURGXSIZE - 0.0767 DAYSXADM + 0.0547 ERXADM
           + 0.0898 SURGXADM + 0.073 AWXADM + 0.046 NWXADM - 0.143
SUPPXADM
           - 0.0192 CAPXADM - 0.0181 SIZEXADM + 0.0269 TEACH

Predictor        Coef       StDev          T        P
Constant        13.32       15.63       0.85    0.396
DAYS           -3.334       1.947      -1.71    0.089
ER              0.907       1.550       0.58    0.560
SURG           0.5040      0.9281       0.54    0.588
AW             -3.272       3.745      -0.87    0.384
NW             -0.937       6.209      -0.15    0.880
SUPP           -2.943       2.021      -1.46    0.148
CAP             1.731       1.327       1.30    0.195
ADM            0.1945      0.8364       0.23    0.816
SIZE            3.762       1.905       1.97    0.050
DAYSXDAY       0.2298      0.2681       0.86    0.393
ERXER         -0.0437      0.1024      -0.43    0.670
SURGXSUR     -0.01631     0.02710      -0.60    0.548
DAYSXER        0.4260      0.2603       1.64    0.104
DAYSXSUR     0.002494    0.004866       0.51    0.609
ERXSURG       -0.0870      0.1070      -0.81    0.417
AWXAW         -2.0001      0.7993      -2.50    0.014
NWXNW          -0.476       2.060      -0.23    0.818
SUPPXSUP       0.2334      0.2515       0.93    0.355
CAPXCAP       0.17199     0.07705       2.23    0.027
ADMXADM       0.02030     0.03232       0.63    0.531
SIZEXSIZ       0.3949      0.2845       1.39    0.168
AWXNW           3.790       2.333       1.62    0.107
AWXCAP        -0.0592      0.2486      -0.24    0.812
AWXSUPP        1.5501      0.8733       1.77    0.078
NWXSUPP        -0.456       1.029      -0.44    0.658
NWXCAP        -0.2076      0.3777      -0.55    0.583
CAPXSUPP      -0.1670      0.1525      -1.09    0.276
DAYSXAW        1.1520      0.4380       2.63    0.010
DAYSXNW       -0.7012      0.5800      -1.21    0.229
DAYSXCAP      -0.0588      0.1539      -0.38    0.703
```

```
DAYSXSUP        0.1641      0.2430        0.68    0.501
ERXCAP         -0.2627      0.1114       -2.36    0.020
SURGXCAP       0.07658     0.06847        1.12    0.266
ERXAW          -0.7325      0.2943       -2.49    0.014
ERXNW           0.7679      0.3992        1.92    0.057
ERXSUPP         0.3295      0.1314        2.51    0.013
SURGXAW        -0.4064      0.2248       -1.81    0.073
SURGXNW         0.2789      0.2519        1.11    0.270
SURGXSUP      -0.16799     0.09185       -1.83    0.070
SIZEXAW        -0.5970      0.3729       -1.60    0.112
SIZEXNW        -0.1348      0.5461       -0.25    0.805
SIZEXCAP        0.1245      0.1446        0.86    0.391
SIZEXSUP        0.0608      0.2291        0.27    0.791
DAYSXSIZ       -0.1440      0.2713       -0.53    0.597
ERXSIZE        -0.3485      0.1411       -2.47    0.015
SURGXSIZ      -0.06878     0.05725       -1.20    0.232
DAYSXADM      -0.07667     0.07266       -1.06    0.293
ERXADM         0.05466     0.04918        1.11    0.268
SURGXADM       0.08983     0.04877        1.84    0.068
AWXADM          0.0734      0.1502        0.49    0.626
NWXADM          0.0459      0.1870        0.25    0.806
SUPPXADM      -0.14282     0.07980       -1.79    0.076
CAPXADM       -0.01923     0.04508       -0.43    0.670
SIZEXADM      -0.01813     0.06476       -0.28    0.780
TEACH          0.02688     0.02344        1.15    0.254

S = 0.1373      R-Sq = 98.3%     R-Sq(adj) = 97.6%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        55    142.1859      2.5852    137.22    0.000
Residual Error   128      2.4115      0.0188
Total            183    144.5975



Unusual Observations
Obs       DAYS       COST        Fit   StDev Fit    Residual    St Resid
  2       11.3    19.2688    19.0038      0.0663      0.2651       2.21R
 10        8.7    16.3762    16.1433      0.0751      0.2329       2.03R
 32        9.3    16.5309    16.7295      0.1020     -0.1986      -2.16R
 57        8.9    17.4678    17.6220      0.1188     -0.1542      -2.24R
 60        9.9    18.1313    17.4521      0.0825      0.6792       6.19R
 66        7.9    16.4602    16.0223      0.1043      0.4379       4.91R
 72        9.1    16.6564    16.8706      0.1219     -0.2143      -3.40R
 79       11.4    18.5026    18.2523      0.0899      0.2502       2.41R
 85        8.3    15.8041    15.9739      0.1144     -0.1698      -2.24R
104        9.8    17.3408    17.1731      0.1165      0.1677       2.31R
155       11.2    18.4682    18.7310      0.0524     -0.2628      -2.07R

R denotes an observation with a large standardized residual

Saving file as: C:\My Documents\finalversionofregressions.MPJ
```

Appendix C

MINITAB Regression output used for Goldfeld-Quandt Test for Heteroscedasticity

Regressions below are used for Goldfeld-Quandt test for heteroscedasticity. The null hypothesis is homoscedasticity. Degrees of freedom equal F(15/15). We dropped 24 observations. If computed statistic is greater than F, then we reject null.
In this case for TL using Nursing hours, we calculated F=1.03. 5% critical value equals 2.40, so we do not reject null.

Current worksheet: goldquant1.xls

Regression Analysis

```
The regression equation is
COST = 94.3 - 10.8 DAYS - 2.52 ER + 4.12 SURG - 0.4 AW - 33.7 NW - 24.8
SUPP
           + 8.74 CAP + 6.69 ADM + 4.21 SIZE + 6.66 NH - 0.72 DAYSXDAYS
           + 0.095 ERXER - 0.016 SURGXSURG + 1.50 DAYSXER + 0.0086
DAYSXSURG
           - 0.266 ERXSURG - 2.05 AWXAW + 0.42 NWXNW + 0.409 CAPXCAP
           + 1.30 SUPPXSUPP + 0.356 ADMXADM - 1.69 SIZEXSIZE + 0.374
NHXNH
           + 7.0 AWXNW + 0.566 AWXCAP - 2.85 AWXSUPP + 10.2 NWXSUPP
           - 1.57 NWXCAP - 0.094 CAPXSUPP - 0.88 DAYSXAW + 1.95 DAYSXNW
           - 0.061 DAYSXCAP + 0.788 DAYSXSUPP - 0.772 ERXCAP + 0.052
SURGXCAP
           + 0.227 ERXAW + 1.46 ERXNW + 0.474 ERXSUPP + 0.368 SURGXAW
           - 1.47 SURGXNW - 0.137 SURGXSUPP - 0.22 SIZEXAW + 0.31
SIZEXNW
           - 0.291 SIZEXCAP - 0.460 SIZEXSUPP - 0.76 NHXAW + 0.46 NHXNW
           - 0.713 NHXCAP - 0.469 NHXSUPP + 1.25 DAYSXSIZE - 0.943
DAYSXNH
           + 0.257 SURGXNH + 1.12 SIZEXNH + 0.623 ERXNH - 0.588 ERXSIZE
           + 0.167 SURGXSIZE - 0.136 DAYSXADM - 0.209 ERXADM + 0.001
SURGXADM
           + 0.144 AWXADM - 1.53 NWXADM - 0.351 SUPPXADM + 0.118 CAPXADM
           - 0.080 SIZEXADM + 0.132 NHXADM + 0.0639 TEACH

Predictor        Coef       StDev          T        P
Constant        94.35       45.51       2.07    0.059
DAYS          -10.767       6.249      -1.72    0.109
ER             -2.519       3.755      -0.67    0.514
SURG            4.117       3.143       1.31    0.213
AW              -0.35       19.58      -0.02    0.986
NW             -33.70       25.92      -1.30    0.216
SUPP           -24.82       11.12      -2.23    0.044
CAP             8.744       4.210       2.08    0.058
ADM             6.694       3.064       2.18    0.048
SIZE            4.214       4.633       0.91    0.380
```

```
NH              6.665        7.575         0.88    0.395
DAYSXDAY       -0.720        1.254        -0.57    0.576
ERXER          0.0954       0.2212         0.43    0.673
SURGXSUR      -0.0160       0.1079        -0.15    0.884
DAYSXER        1.4992       0.8444         1.78    0.099
DAYSXSUR      0.00856      0.01243         0.69    0.503
ERXSURG       -0.2659       0.4899        -0.54    0.596
AWXAW          -2.048        3.475        -0.59    0.566
NWXNW           0.416        9.690         0.04    0.966
CAPXCAP        0.4086       0.1859         2.20    0.047
SUPPXSUP        1.297        1.098         1.18    0.258
ADMXADM        0.3555       0.1665         2.13    0.052
SIZEXSIZ       -1.690        1.541        -1.10    0.293
NHXNH          0.3744       0.5959         0.63    0.541
AWXNW            6.96        12.29         0.57    0.581
AWXCAP         0.5658       0.5851         0.97    0.351
AWXSUPP        -2.850        3.285        -0.87    0.401
NWXSUPP        10.189        5.943         1.71    0.110
NWXCAP        -1.5713       0.9352        -1.68    0.117
CAPXSUPP      -0.0944       0.4526        -0.21    0.838
DAYSXAW        -0.879        1.727        -0.51    0.619
DAYSXNW         1.952        1.984         0.98    0.343
DAYSXCAP      -0.0605       0.4982        -0.12    0.905
DAYSXSUP       0.7876       0.7805         1.01    0.331
ERXCAP        -0.7724       0.3404        -2.27    0.041
SURGXCAP       0.0519       0.2234         0.23    0.820
ERXAW          0.2275       0.6527         0.35    0.733
ERXNW          1.4585       0.8303         1.76    0.102
ERXSUPP        0.4740       0.4846         0.98    0.346
SURGXAW        0.3681       0.7972         0.46    0.652
SURGXNW       -1.4714       0.9382        -1.57    0.141
SURGXSUP      -0.1374       0.3442        -0.40    0.696
SIZEXAW        -0.216        1.089        -0.20    0.845
SIZEXNW         0.310        1.729         0.18    0.860
SIZEXCAP      -0.2913       0.5033        -0.58    0.573
SIZEXSUP      -0.4598       0.6296        -0.73    0.478
NHXAW          -0.756        1.105        -0.68    0.506
NHXNW           0.458        1.804         0.25    0.803
NHXCAP        -0.7135       0.4755        -1.50    0.157
NHXSUPP       -0.4690       0.8882        -0.53    0.606
DAYSXSIZ        1.251        1.260         0.99    0.339
DAYSXNH       -0.9434       0.8962        -1.05    0.312
SURGXNH        0.2570       0.5891         0.44    0.670
SIZEXNH        1.1227       0.7906         1.42    0.179
ERXNH          0.6232       0.5037         1.24    0.238
ERXSIZE       -0.5880       0.5412        -1.09    0.297
SURGXSIZ       0.1669       0.2172         0.77    0.456
DAYSXADM      -0.1363       0.2126        -0.64    0.532
ERXADM        -0.2094       0.1789        -1.17    0.263
SURGXADM       0.0008       0.1484         0.01    0.996
AWXADM         0.1440       0.5917         0.24    0.812
NWXADM        -1.5320       0.7188        -2.13    0.053
SUPPXADM      -0.3513       0.3599        -0.98    0.347
CAPXADM        0.1180       0.1508         0.78    0.448
```

```
SIZEXADM      -0.0796      0.2234      -0.36    0.727
NHXADM         0.1319      0.2896       0.46    0.656
TEACH         0.06392     0.03557       1.80    0.096

S = 0.09225     R-Sq = 99.5%     R-Sq(adj) = 96.9%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        66    21.83927     0.33090     38.88    0.000
Residual Error    13     0.11064     0.00851
Total             79    21.94991


Unusual Observations
Obs       DAYS       COST          Fit   StDev Fit    Residual    St Resid
 19        9.4    16.6032     16.7824      0.0561     -0.1792      -2.45R
 20        7.9    16.4602     16.4605      0.0919     -0.0003      -0.04 X
 22        9.4    17.0053     16.9131      0.0833      0.0922       2.32R
 31        8.0    16.2589     16.2621      0.0919     -0.0032      -0.39 X
 36        9.9    18.1313     18.0984      0.0912      0.0329       2.36R
 43        9.3    16.5309     16.5568      0.0913     -0.0259      -2.00R
 48       10.4    17.6582     17.6574      0.0921      0.0008       0.15 X
 58        9.9    17.1866     17.1873      0.0922     -0.0007      -0.25 X
 79        8.9    17.4678     17.4768      0.0921     -0.0091      -1.53 X

R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.
```

Current worksheet: goldquant2.xls

Regression Analysis

```
The regression equation is
COST = 17.6 - 6.11 DAYS + 9.99 ER - 0.75 SURG - 9.6 AW - 2.1 NW + 4.12
SUPP
           - 4.07 CAP - 0.72 ADM + 5.1 SIZE - 7.13 NH + 0.722 DAYSXDAYS
           - 0.363 ERXER + 0.0081 SURGXSURG - 1.29 DAYSXER + 0.0010
DAYSXSURG
           + 0.078 ERXSURG - 1.63 AWXAW + 0.658 NWXNW - 0.180 CAPXCAP
           + 0.10 SUPPXSUPP + 0.160 ADMXADM - 0.03 SIZEXSIZE + 1.03
NHXNH
           + 1.93 AWXNW + 0.67 AWXCAP - 0.20 AWXSUPP - 2.70 NWXSUPP
           + 0.36 NWXCAP + 0.165 CAPXSUPP + 0.90 DAYSXAW + 2.02 DAYSXNW
           + 0.029 DAYSXCAP - 0.757 DAYSXSUPP + 0.351 ERXCAP - 0.007
SURGXCAP
           - 0.896 ERXAW - 1.53 ERXNW + 0.307 ERXSUPP + 0.092 SURGXAW
           - 0.551 SURGXNW + 0.430 SURGXSUPP + 0.34 SIZEXAW - 1.81
SIZEXNW
           + 0.016 SIZEXCAP + 0.014 SIZEXSUPP - 0.24 NHXAW + 2.86 NHXNW
           - 0.117 NHXCAP - 0.17 NHXSUPP + 0.092 DAYSXSIZE + 1.29
DAYSXNH
```

```
           - 0.417 SURGXNH - 0.01 SIZEXNH - 0.876 ERXNH + 0.160 ERXSIZE
           - 0.135 SURGXSIZE - 0.283 DAYSXADM + 0.345 ERXADM + 0.169
SURGXADM
           - 0.013 AWXADM + 0.832 NWXADM + 0.028 SUPPXADM - 0.203
CAPXADM
           - 0.300 SIZEXADM - 0.349 NHXADM - 0.0069 TEACH

Predictor        Coef       StDev          T        P
Constant        17.62       60.25       0.29    0.775
DAYS           -6.113       8.698      -0.70    0.495
ER              9.990       6.982       1.43    0.176
SURG           -0.748       3.268      -0.23    0.823
AW              -9.62       18.22      -0.53    0.607
NW              -2.11       19.42      -0.11    0.915
SUPP            4.121       6.719       0.61    0.550
CAP            -4.074       4.806      -0.85    0.412
ADM            -0.722       2.876      -0.25    0.806
SIZE             5.11       11.72       0.44    0.670
NH             -7.134       9.481      -0.75    0.465
DAYSXDAY       0.7220      0.9530       0.76    0.462
ERXER         -0.3631      0.3639      -1.00    0.337
SURGXSUR      0.00806     0.08851       0.09    0.929
DAYSXER       -1.2890      0.8550      -1.51    0.156
DAYSXSUR      0.00102     0.01238       0.08    0.936
ERXSURG        0.0784      0.2844       0.28    0.787
AWXAW          -1.626       3.849      -0.42    0.680
NWXNW          0.6582      0.5670       1.16    0.267
CAPXCAP       -0.1799      0.3273      -0.55    0.592
SUPPXSUP        0.097       1.262       0.08    0.940
ADMXADM        0.1600      0.1684       0.95    0.360
SIZEXSIZ       -0.027       1.464      -0.02    0.986
NHXNH           1.035       1.562       0.66    0.519
AWXNW           1.934       5.704       0.34    0.740
AWXCAP          0.673       1.134       0.59    0.563
AWXSUPP        -0.204       3.102      -0.07    0.948
NWXSUPP        -2.699       2.955      -0.91    0.378
NWXCAP          0.356       1.345       0.26    0.795
CAPXSUPP       0.1653      0.4990       0.33    0.746
DAYSXAW         0.900       2.423       0.37    0.716
DAYSXNW         2.019       2.331       0.87    0.402
DAYSXCAP       0.0291      0.5314       0.05    0.957
DAYSXSUP      -0.7572      0.6442      -1.18    0.261
ERXCAP         0.3506      0.4028       0.87    0.400
SURGXCAP      -0.0067      0.1807      -0.04    0.971
ERXAW         -0.8964      0.8413      -1.07    0.306
ERXNW          -1.527       1.455      -1.05    0.313
ERXSUPP        0.3074      0.5023       0.61    0.551
SURGXAW        0.0919      0.9202       0.10    0.922
SURGXNW       -0.5515      0.7304      -0.76    0.464
SURGXSUP       0.4299      0.3427       1.25    0.232
SIZEXAW         0.338       1.886       0.18    0.861
SIZEXNW        -1.807       1.906      -0.95    0.360
SIZEXCAP       0.0164      0.5538       0.03    0.977
SIZEXSUP       0.0141      0.8226       0.02    0.987
```

```
NHXAW          -0.239       1.978      -0.12    0.906
NHXNW           2.863       2.134       1.34    0.203
NHXCAP        -0.1170      0.4789      -0.24    0.811
NHXSUPP        -0.175       1.304      -0.13    0.896
DAYSXSIZ       0.0919      0.9826       0.09    0.927
DAYSXNH        1.2938      0.8067       1.60    0.133
SURGXNH       -0.4171      0.3452      -1.21    0.249
SIZEXNH        -0.013       1.005      -0.01    0.990
ERXNH         -0.8761      0.4820      -1.82    0.092
ERXSIZE        0.1605      0.4408       0.36    0.722
SURGXSIZ      -0.1352      0.3659      -0.37    0.718
DAYSXADM      -0.2830      0.2823      -1.00    0.334
ERXADM         0.3453      0.1691       2.04    0.062
SURGXADM       0.1689      0.1839       0.92    0.375
AWXADM        -0.0130      0.5371      -0.02    0.981
NWXADM         0.8317      0.5687       1.46    0.167
SUPPXADM       0.0285      0.2167       0.13    0.897
CAPXADM       -0.2028      0.2902      -0.70    0.497
SIZEXADM      -0.2997      0.3717      -0.81    0.435
NHXADM        -0.3487      0.2781      -1.25    0.232
TEACH        -0.00688     0.05683      -0.12    0.905

S = 0.09384     R-Sq = 99.3%     R-Sq(adj) = 96.0%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression        66    17.14336     0.25975     29.50    0.000
Residual Error    13     0.11447     0.00881
Total             79    17.25783


Unusual Observations
Obs       DAYS       COST         Fit   StDev Fit    Residual    St Resid
  6        9.8    17.3408     17.3479      0.0937     -0.0071       -1.37 X
 14       10.8    18.4420     18.4435      0.0935     -0.0015       -0.19 X
 20       10.8    17.9484     17.9411      0.0937      0.0073        1.45 X
 33       10.7    17.5316     17.5239      0.0934      0.0077        0.84 X
 43       11.1    18.6144     18.6144      0.0938     -0.0001       -0.34 X
 49       10.3    18.3714     18.3813      0.0936     -0.0099       -1.41 X
 60       11.2    18.9347     18.9686      0.0925     -0.0339       -2.17R
 66       11.0    18.2447     18.3676      0.0757     -0.1229       -2.22R
 71       11.2    18.6789     18.6051      0.0887      0.0738        2.40R
 75       11.5    19.2453     19.2371      0.0934      0.0082        0.89 X
 80       10.5    18.5450     18.5023      0.0915      0.0427        2.07R
R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.
```

Vita

Michael J. Evans

Michael Evans was born on October 26, 1968 in Falls Church, Virginia. He earned his Bachelor of Science degree in Economics from George Mason University. He has been employed in the Healthcare Industry since completing his undergraduate studies and now holds a position as a Senior Systems Analyst with INOVA Health System.