AN ECONOMIC ANALYSIS OF INFORMATION SYSTEMS BUDGETS

Vijay Gurbaxani
Kenneth Kraemer

Center for Research on Information Technology and Organizations
Graduate School of Management
University of California, Irvine
Irvine, CA 92717

Nicholas Vitalari
The Concours Group
800 Rockmead Drive
Kingwood, TX 77339

Final Revision December 1996

Acknowledgments: This research was supported in part by grants from the National Science Foundation and Computer Sciences Corporation.

An Economic Analysis of Information Systems Budgets

Vijay Gurbaxani
Kenneth Kraemer
Nicholas Vitalari

ABSTRACT

This paper conducts an empirical analysis of information systems budget data focusing on the implications for the efficient production of information services. We use a model of the production of information services based on the economic theory of production to develop testable hypotheses for budget behavior. In particular, we focus on two important issues: i) the allocation of the information systems budget to its two largest components -- personnel and hardware, and ii) the existence of scale economies in the provision of information services. These issues are examined using budget data collected through a survey of information systems managers in Fortune 500 corporations. We find that the optimal ratio of personnel to hardware expenditures is independent of the scale of the information systems organization for a given set of prices, and that there are no measurable economies of scale in the provision of information services. The implications of the analysis for the management of information services are discussed.

1. Introduction

With the rapid growth in the use of information technologies, companies are continually confronting the question of how to efficiently manage the production of information services. Efficient production focuses on delivering the optimal level of services at least cost. Naturally, the optimal scale will depend on the costs of service provision. The costs of delivering information services are driven in large part by the unit costs of the two major inputs in the production process for information systems, personnel and hardware, which are notably different. While hardware costs are declining rapidly over time, labor costs are constant or increasing slowly, resulting in a dramatic reduction in the relative cost of hardware (Gurbaxani, 1990). Correspondingly, efficient production requires that information systems managers continually exploit this relative cost advantage by increasing the hardware (or capital) intensity of the production process through the substitution of hardware for labor. In this paper, we examine the role of capital intensity in the provision of information services and the optimal scale of information systems in an organization - two issues that are central to efficient production.

Since information systems (I/S) budgets reflect the underlying techniques for the production of information services, the analysis of budget data can provide considerable insights into the nature of the production process and useful benchmarks for best practice. In order to examine the optimal scale of information services in an organization, and the efficient allocation of resources to its two major inputs, hardware and labor, this paper conducts a rigorous empirical analysis of I/S budget data from Fortune 500 firms. We use a model of the production of information services based on the economic theory of production to develop testable hypotheses for budget behavior. Production theory facilitates the analysis of important managerial and production decisions related to the provision of information services.

The capital intensity of a production process has been used in many settings as a measure of production efficiency. As capital costs decline relative to labor costs, substituting capital for labor will make the production process more efficient. In I/S, where the costs of hardware have been dropping rapidly, one would expect to observe ever-increasing capital intensity. I/S managers would clearly benefit from understanding capital-labor tradeoffs in the I/S production process. Specifically, managers require knowledge of the optimal capital-labor ratio, its relationship to scale and to industry sector, and specific I/S practices that facilitate greater capital intensity. An understanding of the trends in the optimal labor-capital ratio has been limited by the lack of firm-level analysis. In this paper, we examine the ratio of the major input factors, hardware and personnel, measured by the allocation of I/S budgets to the individual budget categories. We further focus on developing an understanding of the impact of specific production practices on the optimal labor-capital ratio, and of scale and industry sector on this ratio.

We also investigate the existence of economies of scale in the provision of information services[1] and examine the resulting implications for the allocation of the overall I/S budget. In theory, the optimal scale should be determined by an analysis of the return on investment in information systems. In practice, determination of this payoff is extremely difficult and organizations often use efficiency benchmarks to evaluate their own scale of investment. The ratio of the overall I/S budget to corporate revenues is widely used as such a measure in I/S practice. Yet the scarcity of consistent data on I/S budgets at the firm level has resulted in the lack of any formal analysis to determine even whether this measure is statistically meaningful in that a relationship can be shown to exist between the I/S budget and revenues. Moreover, it is not known whether or how this ratio is affected by factors such as the scale of the I/S function and the corporation's industry sector. Our approach addresses a key subproblem in determining the optimal scale - namely whether the provision of information services displays constant, increasing or decreasing returns to scale. It raises the question of whether larger organizations spend proportionately less on I/S than smaller organizations, which is useful to senior managers who must determine the scale of I/S in an organization.

The outline of this paper is as follows. The theory and hypotheses are presented in Section 2. The data are described in Section 3. The results of the analysis are presented in Section 4. The managerial implications of the research and our concluding remarks are in Section 5.

2. Theory and Hypotheses

As discussed above, efficient production is mainly concerned with providing the optimal level of service at the least cost. In the I/S context, this translates into choosing a set of production and managerial practices that optimally utilize the two major inputs, labor and hardware (capital). Since the most distinctive characteristic of the computer industry is the rapid exponential decline in the unit costs of hardware, it stands to reason that I/S managers should attempt to exploit this trend by substituting hardware for labor. The rate at which this substitution can occur will depend on the technical possibilities of trading off hardware for labor. It is worth pointing out that as information systems managers substitute hardware for labor, the costs of providing any given level of information services may decrease. This, in turn, may make new information systems opportunities viable that require additional investment in both hardware and labor.

Accordingly, while information systems environments become increasingly hardware-intensive, the overall level of investment in labor can also increase.

2.1 Labor-Capital Tradeoffs in Information Services

To understand the nature of information services tradeoffs, the activity must be examined in a structured way. Consider the production of information services as a process requiring two major inputs: hardware and labor (including software development effort). Although these inputs have many complex dimensions and are subject to intricate interaction, their tradeoff analysis can be simplified by concentrating discussion on the two major I/S activities: *systems development* and *operations* :

Systems Development

One important aspect of the labor-hardware tradeoff is related to hardware support within the systems development environment itself. Programmer productivity can be enhanced significantly through the provision of increased hardware support, as can be seen in the evolution of the programming environment. For example, improving the response time of an on-line system can have a significant impact on programmer productivity. Thadhani (1984) found that reducing the mean response time on development systems from 2 seconds to 0.25 seconds by increasing processor capacity doubles programmer productivity. Accordingly, the early programming environment, consisting of batch processing on mainframes, evolved into interactive programming on mainframes, then into the use of shared minicomputers, and today consists of dedicated workstation support.

A second trend is the increasing use of programmer productivity tools, such as CASE tools, which increase productivity but require significant hardware support. Other examples include virtual memory operating systems which free programmers from the constraints of having to develop their own paging routines; however, increased hardware investment is needed to support them. The increasing use of sophisticated graphical user interfaces such as Windows 95 typically require dedication of 20 to 25 percent of the hardware resources that are no longer available to applications but are believed to increase productivity. Yet another example is the use of database management systems, which execute many file management tasks that were once in the programmer's domain and typically support non-procedural languages for accessing the underlying databases. Interactive debugging aids, application generators, automated librarians, and program flow analyzers are other examples of hardware intensive tools used to achieve significant gains in programmer productivity (Boehm, 1981).

Another effect is the impact of target hardware capacity specifications upon software development costs. The effort required to fit programs into limited memory, or to achieve higher levels of execution-time performance through more efficient software, can be significantly greater than the effort required to achieve similar performance through more powerful hardware (Boehm, 1981). This effect is especially visible when the target hardware is microprocessor-based, as is often the case.

Operations

Similar tradeoff patterns are observed in operations as well. Many sophisticated automated tools have been developed, often as part of operating systems, to manage data center operations. Thus, many data centers can now be run as "lights out" operations, significantly reducing the support labor needed. The consolidation of data centers is also often seen as a means of achieving reductions in the labor-capital ratio. Similarly, network management tools that allow network administrators to diagnose and solve end-user problems remotely have helped to increase the productivity of these personnel.

By focusing on how the major inputs, labor and hardware, interact in the two major activities that constitute the provision of information services, we have been able to develop some insights into how to efficiently produce information services. It is important to recognize that the above discussion, drawing informally from the economic theory of production, has served to structure the analysis sufficiently to provide some preliminary insight. Given the complex nature of the interactions between the major inputs, formal modeling based on production theory will prove to be of significant value.

2.2 Modeling Information Systems as a Production Process

Our approach involves modeling the production process for information services using a production function that transforms inputs into output. The properties of the production function reflect the nature of producing information services. These include properties of production processes such as scale economies, and the technical possibilities of substitution between inputs. By incorporating the production function in an optimization model that balances the value of the outputs of the production process against its costs, the characteristics of the optimal production strategy can be determined. Several testable implications can be derived from such a model. By empirically testing these hypotheses, it is possible to determine specific characteristics of the production function and as a result the underlying nature of the production process. This, in turn, has normative implications for the management of the production process.

This analysis is based in part on the work of Gurbaxani and Mendelson (1987, 1990, 1992) (see also Gurbaxani, 1990) who developed such a formal model of the provision of information services. Their research was motivated by debates in the literature about the time trends in I/S budgets and their major component categories. Conventional wisdom held that software's (including programming labor) share of the I/S budget would increase according to an S-curve, while the alternative belief (Frank, 1982) was that the budget shares of hardware and software effort remained constant over time. Further, Nolan's (1973) stage hypothesis held that overall I/S budgets grew according to an S-curve, while others (Lucas and Sutton, 1977) argued that this pattern was linear or exponential. Accordingly, the Gurbaxani and Mendelson model provides a framework for analyzing the time pattern of a firm's optimal I/S budget and its allocation between hardware and software effort. They used their model to study the growth patterns of spending by I/S departments aggregated over all corporations in the US for the years 1976-1984. They showed that overall I/S spending in the US. grew exponentially[2], and the ratio of hardware expenditures to software effort expenses stayed constant over time.

Gurbaxani and Mendelson (1987) considered two classes of production functions in their analysis: the fixed coefficient production function and the Cobb-Douglas production function. The fixed coefficient production function does not permit substitution between inputs - it posits that the optimal input mix is a fixed ratio for any level of output and is independent of price. Accordingly, even though the unit price of hardware decreases rapidly, if the production process was adequately modeled by a fixed coefficient production process, I/S managers would not be able to substitute hardware for personnel, and the net result was that labor's share of the I/S budget would increase according to an S-curve.

On the other hand, a Cobb-Douglas production process was consistent with the observed constancy of budget shares of hardware and labor. Note that the Cobb-Douglas function has a unit elasticity of substitution. This implies that, in a single-period analysis, the optimal input ratio of hardware to labor would increase as the relative price of hardware decreased such that the ratio of the budget shares of hardware and labor would be constant. That is, as hardware became progressively less expensive, I/S managers would use more of it and correspondingly less labor (for a fixed level of output), resulting in constant budget shares. Other specifications of production functions such as the CES production function would lead to other outcomes, such as slowly increasing or decreasing budget ratios.

This analysis provided a theoretical framework within which to analyze the production of information services. It showed that the optimal input mix depends mainly on two factors--the substitutability between hardware and labor in the production of information services and the relative prices of the inputs. The results highlighted the importance of substitutability between the two inputs as a means of increasing the efficiency of the I/S function. Gurbaxani and Mendelson conducted analyses at the level of the US economy and focused on the time series aspects of the budget trends.

While the above analysis contributes to our understanding of the aggregate production process underlying information services, it does not directly address the issues that confront an I/S manager who must choose an efficient allocation of resources given a set of firm-level production possibilities. It is particularly important to note that aggregate production processes can be successfully characterized by the Cobb-Douglas production function even when the firm-level production function is quite different. For example, Houthakker (1956) has shown that even when production within firms is done according to a fixed-coefficients production function, the aggregate input-output relationship can take the form of a Cobb-Douglas production function. It is, therefore, important to develop a robust understanding of the nature of this production process at the firm level. Our study complements the earlier studies by focusing on the cross-sectional aspects of the production of information services at the firm level.

2.3 Hypotheses

The Cobb-Douglas production function can be written as

$$(1) \qquad Y = W(L,K) = AL^{a}K^{b}$$

where Y is output, L is labor or personnel, K is capital or hardware, A is a scale constant, a is the output elasticity of labor, and b is the output elasticity of hardware. This production function has a unit elasticity of substitution. It is characterized by diseconomies of scale if $\alpha+\beta<1$, constant returns to scale if $\alpha+\beta=1$, and by economies of scale if $\alpha+\beta>1$. Further, the Cobb-Douglas production function is homothetic. That is, the optimal ratio of labor to capital is independent of scale for a given set of prices (Silberberg, 1978).

We have two main objectives in this paper. First, we examine the characteristics of the optimal labor-capital ratio. Specifically, we seek to understand the relationship of this ratio to the scale of the I/S function and to industry sector. In order to understand the nature of capital intensity in the I/S context, we test whether the production of information services is, indeed, homothetic, at the firm-level. A finding that firm-level production is homothetic will indicate that the optimal labor-capital ratio is independent of the scale of the I/S function. We also examine the relationship between the scale of the I/S function, measured by total spending on information systems, and firm size, measured by revenues, and its dependence on industry sector. We use data on I/S budgets from Fortune 500 firms for the 1990 fiscal year in our analysis. We examine each of these issues in turn below.

Homotheticity of Information Services Production

The issue of budget allocation between the two major inputs is of considerable importance. Economists have long argued that the capital intensity of a production process is a significant determinant of productivity and, by implication, economic growth. One could therefore argue that the labor-capital ratio in I/S is an indicator of efficiency in production. However, the relationship between investments in hardware and personnel in I/S production is not well understood. Specifically, the relationship between the optimal labor-capital ratio and the scale of the I/S function is unknown. A finding of a negative (positive) relationship between the labor-capital ratio and scale would indicate the existence of labor efficiencies (inefficiencies) associated with scale.

Such an analysis must also take into account the dependence of the optimal labor-capital ratio on the mix of I/S activities - applications development and maintenance and operations. Since systems development is usually more labor-intensive than operations, sites with a higher proportion of systems development activities would have higher values of the labor-capital ratio. Moreover, the tradeoff analysis above has suggested that substitution between hardware and personnel in information services production is often achieved through the use of programmer productivity tools that reduce software effort but increase hardware requirements. Accordingly, we hypothesize that I/S departments that utilize these tools should have a lower labor-capital ratio than those that do not.

Define B to be the annual I/S budget, P as the annual expense on personnel, H as the annual expense on hardware, and R as the annual revenue of the corporation.

One model specification that provides a direct test of homotheticity can be written as:

(2) $P / H = C + D. B + e$

where C and D are coefficients and e is the error term. The null hypothesis of homotheticity is that $D=0$. The advantage of such a model is that the estimate of the constant term provides the optimal budget ratio of personnel to hardware. However, such a specification is limited in that it does not allow an examination of the independent relationships between the total I/S budget and the two components, hardware investment and personnel expenses. For example, if both hardware investments and personnel expenses are an increasing function of scale but the ratio of personnel to hardware expenses remains constant (feasible if outside services are a decreasing function of scale), then the above model will be unable to discern this trend.

A more sophisticated model can be developed as follows. We write two equations that relate expenditures on each of the two budget categories to the total expenditures on I/S. Accordingly, we write

(3a) $Log\ H = C_h + D_h. Log\ B + e_h$

and

(3b) $Log\ P = C_p + D_p. Log\ B + e_p$

The null hypothesis of homotheticity is that $D_h = D_p$.

In general, an improvement in efficiency over ordinary least squares (OLS) regression estimates can be obtained by taking into account the lack of independence between the error terms, e_h and e_p, from the two equations, which arises because investments in I/S typically involve joint hardware and personnel expenditures. Hardware acquisitions affect personnel decisions and vice versa, and firm-specific or general business conditions affect both components. The application of Zellner's (1962) Seemingly Unrelated Regression (SUR) model to equation (3) provides estimates that are minimum variance among the class of all linear, unbiased estimators. However, in this special case in which both equations contain the same set of regressors and an equal number of observations the SUR and OLS estimators are identical (Judge et al., 1982). Therefore, either SUR or OLS may be used to estimate equation (3). Under the null hypothesis of homotheticity, the resulting test statistic for equal coefficients follows a distribution that is asymptotically χ^2 with one degree of freedom.

Economies of Scale in Information Services Production

A central question in the production of information services is the relationship of a firm's investment in I/S to its scale. In particular, if the production could be characterized by constant returns to scale, then one would predict that a firm's investments in I/S would be independent of scale. If in fact there were economies (diseconomies) of scale in the provision of information services, one would predict that a large corporation would invest proportionately less (more) in I/S. We use a firm's revenues as the measure of scale. While revenues are an imperfect measure of scale, they are a widely accepted measure of scale in the academic and practitioner communities, and the ratio of I/S budget to corporate revenue is a widely tracked indicator of performance in I/S practice.

The resulting model is specified as:

(4) $$Log\ B = C + D.\ Log\ R + e$$

The null hypothesis of constant returns to scale is given by $D = 1$.

Control variables

In our analysis, we control for the type of industry, manufacturing and services, which has been shown to be an important characteristic affecting the I/S function. Intuitively, manufacturing tends to be more capital-intensive and services more labor intensive, but it is unclear whether this relationship also holds for the production of information services. The distinction between manufacturing and services is important because of the different roles of information in these two sectors. In services, *information is usually the primary product or service*; and it is integral to everything that goes on in a corporation. In manufacturing, information is only one input, either as part of a product or as a means of coordination and control of processes in, and related to, manufacturing (Bell, 1979; Porat, 1977). These differences may have structural implications for the provision of information services.

It is worth addressing the implications of the organizational and political realities of the budgeting process for our analysis. For example, firms are more likely to approve capital investments in profitable years and shrink them in less successful years. Budgets may also be affected by policy decisions like a mandate to reduce personnel costs across the board or by the individual incentives of the I/S manager. While we do not explicitly model these policy effects, we believe that these effects are random across our sample and captured by the residual error terms. Accordingly, the presence of these effects may reduce the efficiency of our estimations, but they would not bias our results in any systematic manner. In our case, as we shall see below, the results of statistical testing clearly depict the consistency of budget behavior in the sample with the predictions from theory, strongly supporting the validity of our results.

3. Data

The data for this analysis is from a survey of I/S expenditures by companies at the I/S unit and corporate levels. The target population to which we generalize is Fortune 500 firms. The sample frame used to represent this population was 225 CSC/Index member companies. The sample consists of 43 companies and 52 I/S units that provided complete responses. Thus, the overall response rate for the sample frame was 20%. In follow-up calls to encourage firms to participate, we learned that the single most important factor influencing the decision not to participate was the effort required to complete the questionnaire. Participating firms reported that they spent about 45-60 person-hours completing the entire questionnaire, with 15-20 hours devoted to the expenditure portion.

The questionnaire, which consisted of corporate and I/S unit components, was completed under the supervision of the CIO or an equivalent officer. Mailing and monitoring of returns was done by CSC/Index. Follow-up for apparent inconsistencies or missing data on completed questionnaires was done by the researchers. Responses such as firm revenues and expenses and overall I/S spending were also compared wherever possible with independent sources including Compustat, the *Computerworld 100* database, and our Intercorporate Measurement Program (IMP) database for prior years.

The expenditure portion of the questionnaire asked about I/S spending for 1990 for I/S units and the corporation as a whole. The expenditure categories were identical for both levels, and detailed explanations were provided indicating what was to be included or excluded for each category. For example, hardware expenses included all hardware purchases, depreciation and lease/rental expenses, maintenance agreements, and necessary supplies for operation of the hardware, including telecommunications hardware. Only telecommunications related to computing were included within the categories; general telecommunications expenses were omitted.

About 85% of all I/S spending was concentrated in the I/S units of the companies in the survey, with the remaining spending being undertaken in individual departments. Of the spending within I/S units, approximately 10% was for outsourcing of all kinds, including training, PC support, time-sharing, contract programmers, and operations outsourcing. No single firm outsourced more than 30% of total I/S spending. Thus, the data used in this analysis represents a significant portion of total I/S spending in the firms in the sample.

The data at the corporate level are summarized in Table 1. The corporations in our sample are large, with mean revenues of over $9B, though the median level is lower at $3.55B. The mean level of I/S expenditures is $294M, and the median is $82.45M. Mean hardware expenditure accounts for 29% of the I/S budget, personnel for 38%, and purchased software for about 7%. The median levels of these budget shares are virtually identical. The mean labor-capital ratio is 1.73, and its median value is 1.36.

The data at the I/S unit level are summarized in Table 2. As expected, the I/S units in our sample are also fairly large. The mean budget is almost $74M, and the median value is around $35M. Hardware accounts for about 27% of the budget, personnel for 42%, and software for 7%. The mean labor-capital ratio is 1.97, while its median value is 1.45, similar to but somewhat higher than the corresponding values at the corporate level.

To validate the representativeness of our sample for Fortune 500 firms, we present in Table 3 the descriptive statistics for our sample along with those for the *Computerworld 100*[3], a database used for independent comparison. The choice of comparison dimensions was dictated by the data available in the *Computerworld 100* for 1990. We selected only companies for which we had responses on all the comparison dimensions: 227 companies from the *Computerworld* database and 40 from the IMP database. Note that the corporations in both databases are large, and that they are comparable on three ratios, corporate revenue per corporate employee, end-user devices per corporate employee, and I/S employees to total employees. T-test analysis of the means of the two samples for these ratios shows that the null hypothesis that these samples are drawn from the same population cannot be rejected at any reasonable level of significance. We conclude that our sample does generalize to Fortune 500 firms.

We also compared our 1990 sample with the Computerworld 100 samples for 1989-1994. We found 1990 to be a reasonably representative year on the same three comparison dimensions. That is, only minor changes occurred over the period and values for the comparison dimensions for 1990 were nearly identical with the average for the period. We therefore conclude that our sample generalizes to Fortune 500 firms for the 1989-1994 time period.

4. Analysis

We conduct our analysis at two levels - the corporation and the I/S unit. Our analysis of the relationship between the labor-capital ratio and the scale of the I/S function is conducted at both levels. This analysis at the I/S unit level is more detailed. It incorporates two additional factors - the share of applications development in the I/S budget, and the impact of programmer productivity tools, specifically CASE. In addition to being the first to investigate capital intensity at the firm-level, we believe that this is the first time that the impact of CASE tools on this measure has been investigated. Moreover, previous analyses of budgets have ignored the impact of the activity mix on the budget shares. The analysis of the relationship between the size of the I/S operation and the scale of the corporation can be conducted only at the corporate level.

Homotheticity of Information Services Production

Our results confirm that the production of information services is indeed consistent with a homothetic production function. Specifically, we find that the labor-capital ratio is independent of the scale of the I/S function at both corporate and I/S unit levels. The results of our analysis are presented in Tables 4-7.

The results of the regression analysis of Model 1 (Table 4) show that it has no explanatory power, consistent with the absence of a scale effect on the labor-capital ratio. The R^2 term is zero in one case and 0.02 in the other. Further, the coefficient of the I/S budget term is statistically equal to zero for both the corporation and the I/S unit. The constant term estimates the value of the labor-capital ratio and is equal to 1.67 in the case of the corporation and 1.83 at the I/S unit level. It should be noted that these values are statistically indistinguishable from one another. This model provides initial confirmation of the hypothesis and suggests a need for more formal testing.

The results of the analysis of Model 2 for the corporation level (Table 5) provide strong support for the hypothesis of homotheticity in the production of information services. Recall that the test of homotheticity is the equality of the coefficients of the budget term in equations (3a) and (3b). In the case of the corporation, these coefficients are 0.954 in the personnel equation and 0.951 in the hardware equation. The Wald test has a χ^2 statistic of 0.00168, and the null hypothesis of equality between the coefficients cannot be rejected at almost any level of significance.

The results at the I/S unit level are similar. Table 6 provides a summary of the results of a model that is based on equation (3) and also includes the percentage share of budget that is allocated to applications development as a control variable. After controlling for applications development, we find the coefficient of the I/S budget term is 0.944 in the personnel equation and 1.05 in the hardware equation. The Wald test has a χ^2 statistic of 1.68, and the null hypothesis of equality between the coefficients cannot be rejected at even the 80% level of significance. Note that the coefficient of the applications development term is positive in the personnel equation and negative in the hardware equation. As discussed above, applications development and maintenance, and operations are the two major activities that constitute the production of information services. Since applications development is more labor intensive than operations, one would expect that I/S units that spend a larger percentage of their budget on applications related activities are likely to spend proportionately more on personnel. In all of the above estimations, the effects of industry sector are insignificant and are not reported.

Use of CASE Tools

In order to develop a more detailed understanding of the underlying nature of the production of information services, we repeated the analysis with a dummy variable that measured the use of CASE tools. We categorized I/S units into two groups - those that actively used CASE tools and those that did not. Our results (Table 7) show that while the CASE variables in the two equations were not statistically significant at the 95% level

-- the coefficient in the hardware equation is significant at the 90% level -- the coefficients have the predicted signs. The coefficient is positive in the hardware equation and negative in the personnel equation, consistent with the hypothesis that programmer productivity tools allow I/S managers to substitute hardware for personnel by reducing development effort at the cost of additional hardware requirements.

Economies of Scale in Information Services Production

Our analysis of the existence of economies of scale in the provision of information services involves estimating equation (4) at the corporate level while controlling for industry effects. The results (Table 8) show that the coefficient of the revenues term is estimated at 0.96 and is statistically significant at the 99% level. A test of the restriction that the coefficient is no different from unity has an F-statistic of 0.233. Accordingly, the hypothesis of no economies of scale in the provision of information services cannot be rejected at any reasonable level of significance. Interestingly, the coefficient of the dummy variable for industry is insignificant, suggesting that industry sector has no impact on a corporation's I/S budget allocation. We speculate that finer industry categorizations may be necessary to measure industry effects.

5. Conclusions and Implications

This paper has provided a cross-sectional analysis of the production of information services at the firm level and at the I/S unit level. It complements earlier work that focused on the aggregate level by Gurbaxani and Mendelson (1987, 1992). Taken together, these studies provide detailed insights into the nature of I/S production. The two issues analyzed in this paper are the focus of many benchmarking studies typically conducted by industry publications such as Computerworld and Information Week. These studies provide survey results that list measures such as the average percentage of corporate revenue allocated to information systems and the budget shares of the various components. They use these data accompanied by anecdotal evidence from successful firms to make ad hoc inferences about the usefulness of the benchmarks and of specific management practices. Yet there has been no systematic analysis to determine whether any of the relationships implicit in the use of these measures exist.

By viewing these relationships in the context of production theory, we were able to analyze the production process formally. We demonstrated the existence of homotheticity in I/S production as is evidenced by the independence of the labor-capital ratio from the I/S scale. This result shows no labor efficiencies are being attained as I/S organizations get larger. We further showed that, to estimate this relationship accurately, the analysis must control for the activity mix - applications development and maintenance and operations. We also have somewhat weaker evidence to support the hypothesis that the use of productivity tools such as CASE tools are an important means with which to achieve capital-labor substitution. Finally, we showed that there is a linear relationship between the size of the I/S budget and corporate revenues. This result shows that, as a corporation grows, its information services function must grow correspondingly. It is important to note that these two sets of results are consistent. Economies of scale often arise when the labor share of a production process decreases with scale. Thus, if the labor share of the I/S budget decreased with the scale of the I/S function, it would be reasonable to expect that the overall I/S budget would grow less than linearly with corporate revenue.

Production theory suggests how these results can be viewed normatively to provide guidelines to managers who are trying to improve I/S efficiency. The linear relationship between I/S budgets and corporation revenues means that senior managers must recognize that growth of the corporation inherently generates requirements for the growth of the I/S function. Indeed, preliminary evidence that we have collected on time trends shows that, with the restructuring and downsizing witnessed in US corporations, I/S budgets have shrunk correspondingly as well. Our results on the shares of the I/S budget allocated to personnel and hardware show that these inputs are indeed net complements and grow together as I/S budgets increase. The numerical estimates for these budget shares are similar to those that have been obtained in the past by the practitioner publications -- Datamation, Computerworld, and Information Week -- and in earlier academic work (Gurbaxani and Mendelson 1987, 1992). This provides evidence at the firm level to support the finding at the aggregate level that, in spite of the rapidly decreasing costs of hardware, I/S budgets are not dominated by personnel expenditures, but rather that I/S managers have successfully exploited the hardware cost trends by substituting hardware for labor.

6. BIBLIOGRAPHY

Banker, R., H. Chang and C. Kemerer, "Evidence on Economies of Scale in Software Development," *Information and Software Technology*, 36, 5 (1994).

Bell, D. "The Social Framework of the Information Society," in M.L Dertouzos and J. Moses (Eds.), *The Computer Age: A Twenty-Year Review* , MIT Press, Cambridge, MA, 1979, 163-211.

Boehm, B.W, *Software Engineering Economics*, Prentice Hall, Englewood Cliffs, NJ, 1981.

Frank, W.L., *Critical Issues in Software*, Wiley, New York, 1983.

Gurbaxani, V., *Managing Information Systems Costs: An Economic Analysis of Hardware-Software Tradeoffs*, ICIT Press, Washington, DC, 1990.

Gurbaxani, V. and H. Mendelson, "Software and Hardware in Data Processing Budgets," *IEEE Transactions on Software Engineering*, SE-13, 9, September, 1987, 1010-1017.

Gurbaxani, V. and H. Mendelson, "An Integrated Model of Information Systems Spending Growth," *Information Systems Research*, 1, 1 (1990), 23-46.

Gurbaxani, V. and H. Mendelson, "An Empirical Analysis of Software and Hardware Spending," *Decision Support Systems*, June, 1992.

Houthakker, H.S., "The Pareto Distribution and the Cobb-Douglas Production in Activity Analysis," *Review of Economic Studies*, 23, (1956), 27-31.

Judge, G.G, R.C. Hill, W. Griffith, H. Luthepohl, and T. Lee, *Introduction to the Theory and Practice of Econometrics*, Wiley and Sons, New York, 1982.

Lucas, H. and J. Sutton, "The Stage Hypothesis S-curve: Some Contradictory Evidence," *Communications of the ACM*, 20, (1977), 254-259.

Mendelson, H., *The Economics of Information Systems Management*, Prentice-Hall, Englewood Cliffs, NJ, 1996, forthcoming.

Nolan, R.L., "Managing the Computer Resource: A Stage Hypothesis," *Communications of the ACM*, 16, (1973), 399-405.

Porat, M.U., *The Information Economy*, U.S. Government Printing Office, Washington, DC, 1977.

Silberberg, E., *The Structure of Economics: A Mathematical Analysis*, McGraw-Hill Hightstown, NJ, 1978.

Thadhani, A.J. "Factors affecting programmer productivity during application development," *IBM Systems Journal*, 23, 1, (1984), 19-35.

Zellner, A., "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests of Aggregation Bias," *Journal of the American Statistical Association*, 57 (1962), 348-368.

Variable	Mean	Median	Standard deviation	Maximum	Minimum
Revenues (R)	9.08B	3.55B	15.00B	69.0B	307M
IS Budget (B)	293.9M	82.45M	733.0M	4.37B	9.96M
Hardware (K)	70.99M	22.3M	173.5M	1.05B	1.42M
Personnel (L)	111.7M	27.7M	327.1M	2.01B	4.3M
Software (S)	15.72M	4.3M	27.09M	131M	0.7M
K/B	0.29	0.28	0.12	0.55	0.06
L/B	0.38	0.37	0.10	0.62	0.15
S/B	0.07	0.06	0.04	0.20	0.02
L/K	1.73	1.36	1.33	6.64	0.28

Table 1. Summary Statistics - Corporate Data

Variable	Mean	Median	Standard deviation	Maximum	Minimum
IS Budget (B)	73.83M	34.84M	102.04M	504.20M	3.04M
Hardware (K)	17.26M	11.80M	18.68M	90.80M	0.31M
Personnel (L)	32.03M	12.60M	52.96M	250.66M	2.00M
Software (S)	4.41M	2.00M	6.14M	25.14M	0.00M
K/B	0.27	0.26	0.12	0.55	0.05
L/B	0.42	0.39	0.13	0.81	0.18
S/B	0.07	0.06	0.04	0.20	0.00
L/K	1.97	1.45	1.50	6.64	0.40

Table 2. Summary Statistics - IS Unit Data

	Secondary Data (N = 227)			IMP Corporations (N = 40)		
Comparison Dimensions	Mean	Median	Standard deviation	Mean	Median	Standard deviation
Corporate revenue	$7.9B	$4.8B	$10.01B	$9.08B	$3.55B	$15B
Corporate I/S expenses	$191.4M	$81.0M	$335.3M	$293.9M	$82.45M	$733.0M
Total I/S staff	1,445	630	2,479	1,692	580	4,309
Total end user devices	20,011	8,600	44,774	27,192	8,022	79,712
No. end user devices per corporate employee	.50	.43	.40	.59	.50	.36
Corporate revenue per corporate employee	$265,794	$187,381	$244,524	$244,223	$190,771	$160,680
Percent I/S spending of corporate revenues	2.42%	2.03%	1.92%	2.88%	2.19%	2.26%
Percent I/S employees of total employees	4.14%	3.15%	3.59%	4.76%	3.66%	3.54%

Table 3. Comparison of IMP with Secondary Database

Dependent variable	Constant	IS Budget	Adjusted R^2	SEE	Sample
Labor Costs/ Capital Costs	1.67*** (7.38)	1.6E-10 (0.55)	0.0	1.328	Corporate N=40
Labor Costs/ Capital Costs	1.83*** (6.97)	2.1E-9 (0.95)	0.02	1.502	I/S Units N=50

*** Significant at the 99% level.

Table 4. Model 1 Results

Dependent variable	Constant	Log IS Budget	SIC	Adjusted R^2	SEE
Log Labor Costs	-0.216 (-0.34)	0.954*** (27.45)	0.06 (0.63)	0.95	0.313
Log Capital Costs	-0.429 (-0.41)	0.951*** (16.83)	-0.05 (-0.32)	0.87	0.508

*** Significant at the 99% level.
N=40

Table 5. Model 2 Results - Corporate Data

Null Hypothesis: C=D

χ^2 statistic: 0.00168
Probability: 0.9673
Null hypothesis cannot be rejected at any reasonable level of significance

Dependent variable	Constant	Log IS Budget	%Application Development	Adjusted R^2	SEE
Log Labor Costs	-0.092 (-0.16)	0.944*** (28.67)	0.745*** (2.70)	0.94	0.288
Log Capital Costs	-2.00 (-1.72)	1.050*** (16.07)	-1.37*** (-2.50)	0.84	0.572

*** Significant at the 99% level.
N=49

Table 6. Model 2 Results - IS Unit Data

Null Hypothesis: C=D
χ^2 statistic: 1.68
Probability: 0.20
Null hypothesis cannot be rejected even at the 80% level of significance.

Dependent variable	Constant	Log IS Budget	%Applications. Development	I-CASE	Adjusted R^2	SEE
Log Labor Costs	-0.225 (-0.384)	0.953*** (28.84)	0.777*** (2.85)	-0.141 (-1.30)	0.94	0.286
Log Capital Costs	-1.655 (-1.44)	1.028*** (15.87)	-1.46 (-2.72)***	0.365 (1.71)	0.85	0.562

*** Significant at the 99% level.
N=49

Table 7. Model 2 Results - IS Unit Data

Null Hypothesis: C=D

χ^2 statistic: 0.879
Probability: 0.35
Null hypothesis cannot be rejected at any reasonable level of significance.

Dependent variable	Constant	Log Revenues	SIC	Adjusted R^2	SEE
Log IS Budget	-2.80 (-1.40)	0.96*** (10.61)	0.27 (1.15)	0.74	0.722

*** Significant at the 99% level.
N=39

Table 8. Returns to Scale Results - Corporate Data

Null Hypothesis: D=1
F-statistic: 0.233

Probability: 0.632
Null hypothesis cannot be rejected at any reasonable level of significance.

7. Endnotes

[1] While the issue of economies of scale in hardware (Mendelson (1996) and in software development at the project level (Banker, Chang and Kemerer (1994) has received considerable attention, the difficulty of obtaining firm level data has resulted in a notable lack of attention to the existence of economies of scale in the overall provision of information services.

[2] Gurbaxani and Mendelson (1990) showed that, for the years 1960-1987, the pattern of growth of aggregate spending on information systems follows a price-adjusted S-curve, with the early years characterized by S-curve growth and subsequent years described by a steady-state exponential growth pattern.

[3] While Computerworld only publishes the results for the Premier 100, their database contains data on many more firms.