

December 2002

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Mark Anderson

*The University of Texas at Dallas*

Rajiv Banker

*The University of Texas at Dallas*

Nan Hu

*The University of Texas at Dallas*

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## Recommended Citation

Anderson, Mark; Banker, Rajiv; and Hu, Nan, "ESTIMATING THE BUSINESS VALUE OF INVESTMENTS IN INFORMATION TECHNOLOGY" (2002). *AMCIS 2002 Proceedings*. 165.

<http://aisel.aisnet.org/amcis2002/165>

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# ESTIMATING THE BUSINESS VALUE OF INVESTMENTS IN INFORMATION TECHNOLOGY

**Mark Anderson, Rajiv D. Banker, and Nan Hu**

The University of Texas at Dallas

andersmc@utdallas.edu    rbanker@utdallas.edu    nh45@utdallas.edu

## Introduction

Recent studies of the business value of information technology (IT) relate the market value of firms to IT spending or IT capital using a linear specification of the relation between the business value of IT and IT investment. A linear specification implicitly assumes that returns to IT investments do not diminish as the level of IT spending or capital increases, inconsistent with economic theory. In the study described here, we specify a model that has the property of diminishing returns to investments in IT. Using data on IT spending from *InformationWeek* surveys, we provide support for an empirical specification that incorporates diminishing returns to IT spending.

Companies cannot obtain sustainable competitive advantage through investments in IT alone because IT can be easily imitated (Clemons and Row 1991). This suggests that the business value of IT increases with a firm's investment in IT and decreases with investment by its industry peers. On the other hand, investment in new IT by many firms in an industry could lead to positive externalities that benefit the industry as a whole. For example, investments in systems that enable firms to interact more effectively with suppliers and customers may encourage greater investment in IT throughout the supply chain. We test whether or not industry peer IT spending has a negative impact on the value of firm IT spending and find that it does not.

## Research Objectives

### *Literature Review*

Early studies of the business value of IT failed to find positive productivity or earnings improvements associated with investments in IT (Loveman 1994). The fact that many companies were making large investments in IT but researchers were unable to detect productivity improvements was dubbed the "productivity paradox" (Brynjolfsson 1993). But a number of empirical problems limited the effectiveness of the early studies. Obtaining reliable data on IT investment for a sufficiently large group of companies was difficult. Since it takes time for costs or profits to reflect improvements in productivity from IT investments, there were problems matching the appropriate time period for measuring performance with the time period when investment was measured. Brynjolfsson and Hitt (1996) were able to overcome many of the empirical problems in an empirical analysis that compared the productivity of IT capital with other types of capital. They used data on a large sample of firms collected by International Data Group and found higher marginal productivity for IT capital than for other capital.

Recent studies have related the market value of the firm to IT capital or IT spending. Brynjolfsson and Yang (1999) found that IT assets had a higher multiple of stock-price-based market value to asset-based market value than the other asset groups. Bharadwaj, Bharadwaj, and Konsynski (1999) related Tobin's  $q$  (the ratio of the market value of a firm's assets to their replacement value) to IT spending reported in *InformationWeek* surveys during the period 1989-1993. They found significantly positive relations between Tobin's  $q$  and the linear IT spending term in the four years that they studied. In these models, the IT variables were included as linear terms. This implicitly assumes that return on IT investments does not diminish contrary to traditional economic analyses of investment.

### *Research Hypotheses*

Consider an IT valuation model

$$Y_i = \alpha + \beta_1 X_i^\lambda + \beta_2 X_i + \varepsilon_i \quad (1)$$

$$0 < \lambda < 1$$

where  $Y_i$  = the net business value generated by firm  $i$ 's IT investment and  $X_i$  = the cost of the IT investment made by firm  $i$ . If returns to IT investment diminish with the amount of investment, then the coefficient on the concave term  $X_i^\lambda$  would be significantly positive and the coefficient on the linear term would be significantly negative.

*Hypothesis 1: In an empirical specification that relates the value of the firm to IT spending, the coefficient on the concave term is positive and the coefficient on the linear term is negative.*

The relative influence of peer spending on the value of IT investment may be evaluated by including another term in the model that measures the magnitude of IT spending by competitors. If the business value of IT is reduced by peer IT spending, the coefficient on the industry IT spending variable will be negative.

*Hypothesis 2: In an empirical specification that relates the value of the firm to both firm and industry IT spending, the coefficient on the industry spending term is negative.*

## Empirical Analysis

### Estimation Model

We estimate a model that is similar to the model estimated by Bharadwaj, Bharadwaj, and Konsynski (1999) relating Tobin's  $q$  to IT spending. In their model, they included four firm-specific independent variables (market share, advertising expenditure, R & D expenditure, and extent of diversification) and four industry-level independent variables (industry concentration, industry capital intensity, industry average  $q$  and regulated) in addition to the IT spending variable. Our model includes all of the non-IT firm-specific and industry variables in the Bharadwaj et al. model and three IT spending terms: a concave firm-level IT spending term, a linear firm-level IT spending term, and a concave industry-level IT spending term.

In our model, the coefficient on the concave firm-level term represents the direct value impact of the firm's own IT investment. We operationalize this model by setting the exponential term  $\lambda = 1/2$ . The coefficient on the linear firm-level term represents the cost of the firm's IT investment. According to hypothesis 1, the predicted sign on the concave firm-level term is positive and on the linear firm-level term is negative. The concave industry-level term enables us to test whether the value of firm IT investment is affected by investment by its industry peers. According to hypothesis 2, the coefficient on the concave industry-level term should be negative.

### Data Description and Estimation Results

We estimate the empirical model separately for the years 1994, 1995, and 1996 using IT spending values reported in *InformationWeek* surveys. For our measure of industry-level IT spending, we use the median level of IT spending based on the reported IT spending for all other firms in the same industry included in the *InformationWeek* survey. Other data items were obtained from Compustat. We use White's (1980) test to ensure that heteroskedasticity does not affect the estimation results and we remove influential observations using recommended cutoffs for leverage points, Studentized residuals, the DFFITS measure, and standard influences of observations on the covariance of estimates (Belsley, Kuh and Welsch 1980, Krasker, Kuh and Welsch 1983).

The coefficients on the concave IT spending term are significantly positive in all three years and the coefficients on the linear IT ratio term are significantly negative in all three years, consistent with hypothesis 1. The coefficient on the industry median spending term is not significantly different from zero, indicating that the level of industry investment does not reduce the business value of firm IT spending, inconsistent with hypothesis 2. A specification test indicates that the square root model that we estimated is preferred to a linear model. We also use other values for the exponential term  $\lambda$ , such as  $1/4$  and  $3/4$ , and find similar results. Specification tests indicate that these other specifications are not preferred to the square root specification.

## Conclusion

Recent studies relating the stock-price-based value of firm assets to information technology (IT) capital or spending have specified business value ratios, such as Tobin's  $q$ , as linear functions of IT intensity. Implicit in this linear specification is an assumption that returns to IT spending do not diminish as IT intensity increases. We model the business value of IT spending using an alternative functional form where the business value ratio is concave in IT intensity and find support for the hypothesis that the valuation benefits of IT spending are indeed concave in IT spending intensity. Our results also indicate that competitor spending does not reduce the business value of firm IT spending.

Our findings contribute to the literature on the business value of IT in a number of ways. They provide another level of support for the general finding of positive returns to IT investment by demonstrating that returns to IT have the economic property of diminishing returns. If returns to IT investment did not diminish, then the optimal strategy would be to invest in IT indefinitely. They show that empirical analysis that does not use a concave specification may lead to misleading interpretation of the value impact of IT investment. Our finding that the business value of IT is not reduced by the magnitude of industry peer investment indicates that positive externalities of IT investment by firms in an industry may offset negative competitive effects.

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