Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 1996 Proceedings

Americas Conference on Information Systems (AMCIS)

8-16-1996

Information Technology Investments and Firm Performance

Brian L. Dos Santos
College of Business & Public Administration, University of Louisville, bldoss01@homer.louisville.edu

S. Rajagopalan
Department of Management Science and Systems, SUNY Buffalo, mgmtrao@acsu.buffalo.edu

Raghav H. Rao
Department of Management Science and Systems, SUNY Buffalo, mgtrajag@ubvm.cc.buffalo.edu

Baik Yank
Department of Management Science and Systems, SUNY Buffalo

Information Technology Investments and Firm Performance

[Brian L. Dos Santos]
College of Business & Public Administration, University of Louisville, Louisville, KY 40292. E-mail: bldoss01@homer.louisville.edu
[S. Rajagopalan], [Raghav H. Rao], and Baik Yang
Department of Management Science and Systems, SUNY Buffalo, Amherst, NY 14260. E-mail: (Rao) mgmtrao@acsu.buffalo.edu; (Rajagopalan) mgtrajag@ubvm.cc.buffalo.edu

Introduction

In the last decade there have been a few studies that suggest that the large investments in information technology (IT) have not produced the anticipated benefits and these studies have received a good deal of coverage in the business press. This has renewed interest in studies that assess the relationship between IT investments and performance. A careful review of the research linking IT investment and productivity, led Brynjolfsson (1993) to conclude that the work in this area raises concerns regarding measures and methods used for productivity assessment. In essence, the research to date will not convince skeptics that IT investments improve productivity or increase business value.

In this paper, we report results of an empirical study that examines the relationship between IT investments and firm performance. Our analysis is at the firm level. We use data from Computerworld, DISCLOSURE and COMPUSTAT databases, and 10-K reports. Our analysis of this data differs from earlier research studies that have used some of this data, in four ways: (1) we use novel methods for analyzing the sample data; (2) we consider possible lags between IT investments and firm performance; (3) our models include many control variables to account for other factors that could explain performance differences; and (4) we use a more extensive data set; covering five years of IT investment data.

Our results suggest that IT investments aimed at improving a firm's human capital have a positive impact on firm performance, measured by return on investment (ROI), but the effects lag the investment. Investments in other IT inputs (e.g., hardware) have no effect on performance. Interestingly, the impact of IT investments on performance is negatively related to firm size. The smaller the firm, the greater the benefits of IT investments.

The Data

The data for this study was obtained from four sources: annual articles in *Computerworld* that included IT investment data for firms that were best at managing IT, DISCLOSURE databases, company annual 10-K reports, and COMPUSTAT databases. Between 1988 and 1992, *Computerworld* published a list of 100 firms that best manage IT (*Computerworld*, 1988; 1989; 1990; 1991; 1992). Included in these articles were IT investment data that was obtained from each of the firms in the list, broken down into different categories. The data included: (1) mainframe/mini processor market value as a percentage of revenue; (2) IS budget as a percentage of revenue; (3) IS staff expenditures as a percentage of IS budget; (4) IS training investments as a percentage of IS budget; and (5) the number of PCs and terminals per employee (Computerworld, 1988). To minimize the bias caused by using ratio variables with different denominators, we normalized the data.

Other data used in this study were obtained from the sources listed above. Firm performance is measured by return on investments (ROI); a measure often used in the management literature (e.g., Chakravarthy, 1986; Mahmood & Mann, 1993). The Compuserve lists produced 485 possible observations for our study. We had to drop some observations because some of the data required was not available from the DISCLOSURE and COMPUSTAT databases and 10K reports. We were left with 460 observations for our analysis.

Analysis

The five IT investment variables were found to be highly correlated. This presented problems (multicollinearity) because we wished to use the data as independent variables in regression models. Even if multicollinearity does not lead to a biased coefficient, the point-wise test statistic such as t-score could be incorrectly estimated and the measures could be inefficient (Greene, 1993). In a recent study with a subset of this data, Scott (1994) constructed a single latent structure from IT investment measures called "IS effectiveness." She used confirmatory factor analysis to verify a single latent structure. We used exploratory factor analysis to reveal the latent factor structure. Eigen values and an examination of scree-plots indicated that there are two factors. Principal component analysis with varimax rotation for a two-factor structure produced factor loadings with two variables having high loadings on factor 1 (IS staff expenditures and IS training investments) and three variables with high loadings on factor 2 (IS budget by revenue, current market value of major hardware and the number of PCs & terminals). This factor structure is stable over the five year period for which data were available (Table 1). This factor structure is consistent with recent management literature dealing with competence-based sustainable competitive advantage (Lado & Wilson, 1994). The variables with a high loading on factor 1 represent investments that improve human resources (staff & training), while variables with a high loading on factor 2 represent investments in other inputs (hardware & software) which may represent firm's endowed resource set. Instead of the raw investment data, we use factor scores in our analysis.

Table 1. Factor loadings of IT investment measures by year[a]

			Variable				
Year	Factor	Variance explained by each factor	IS budget by revenue	Current market value of major hardware	The number of PC & terminals installed	IS staff expenditures (normalized by revenue)	IS training investments (normalized by revenue)
1988	I	2.040	0.143	-0.072	-0.039	0.482	0.481
.	II	1.407	0.598	0.519	0.284	-0.017	-0.043
1989	I	2.065	0.131	-0.112	-0.077	0.499	0.495
.	II	1.282	0.496	0.507	0.467	-0.066	-0.093
1990	I	2.239	0.239	-0.223	0.055	0.443	0.451
.	II	1.052	0.350	0.676	0.516	-0.116	-0.167
1991	I	2.539	0.192	0.160	-0.174	0.418	0.413
.	II	1.099	0.358	0.318	0.766	-0.143	-0.171
1992	I	2.581	-0.070	-0.130	0.015	0.534	0.509
.	II	1.360	0.465	0.441	0.360	-0.114	-0.557

a This factor structure is from varimax rotation. Reported values are standardized scoring coefficients.

The model used in our analysis is:

$$
\begin{aligned}
ROI_t = {} & \alpha + \beta_{1,i} IT1_{t-i} + \beta_{2,i} IT2_{t-i} + \beta_{1,i} IT1^2{}_{t-i} \\
& + \beta_{2,i} IT2^2{}_{t-i} + \delta_{1i} S_{t-i} + \gamma_{1i} IT1_{t-i} S_{t-i} \\
& + \gamma_{2i} IT2_{t-i} S_{t-i} + \sum_i \phi_{1i} Yi + \sum_{j=1}^{9} \sum_i \eta_{1i} IDj + \varepsilon_t
\end{aligned}
$$

A brief description of the variables in the model follows.

i (= 1,.., 4) represents number of years that performance lags investment, and j (= 1,.. ,9) represents industries.

$IT1_{t-i}$ & $IT2_{t-i}$ represent the two IT investment variables for the two measures obtained from the factor analysis,

$IT1^{2}{}_{t-i}$ & $IT2^{2}{}_{t-i}$ are square terms for the IT investment variables.

S_{t-2}: is a measure of firm size. Firm size is included as a control variable because there exist significant economies of scale in many industries (Hall & Weiss, 1967).

$IT1_{t-i}*S_{t-i}$ & $IT2_{t-i}*S_{t-I}$ are interaction variables of IT investment and firm size.

Yi represents four dummy variables for years. 1992 is the base year. Because we use quasi-panel data (some firms appear more than once in the sample).

IDi represents nine dummy variables for different industries, to control for possible differences in effects across industries.. There are 10 industries represented in the sample. A dummy variable is included for each industry, except the Utility industry.

Our analysis revealed the presence of multicollinearity; a problem we dealt with using Darlington's (1990) weighted-effects coding method. We are interested in the βs and γs. Note that the equation above specifies a one, two, three, and four year lag between IT investments and firm performance. The models are estimated using least squares.

Results

The results are presented in Table 2. Each year has two columns, one without the size and investment interaction terms and the other with interaction terms. The results indicate that input-based IT investments composed of firm's endowed resource set have a positive impact on firm performance, but these performance effects may only be obtained a few years after the investments are made. The results support recent studies (Weill, 1992, Dos Santos and Peffers, 1995) and assertions that there may be significant lags between IT investments and firm performance (Brynjolfsson, 1993). Investments aimed at improving human resources did not appear to affect performance.

Table 1. Regression analysis results with ROI as the dependent variable.

Variable \ ROI	1 year lag		2 year lag		3 year lag		4 year lag	
Constant	0.061**	0.061**	0.051*	0.049*	0.051*	0.052*	0.065*	0.067*
Factor1	-0.007	-0.008	0.002	0.0001	0.004	0.006	0.002	0.008
(Factor1)^2	0.001	0.003	-0.002	-0.0005	-0.0004	-0.002	-0.002	-0.007
Factor2	0.009	0.009	0.018+	0.018+	0.040**	0.040**	0.028+	0.027+
(Factor2)^2	-0.001	-0.001	-0.002	-0.002	**-0.016****	**-0.017****	**-0.015***	**-0.014***
C_size[d]	-1.230	0.547	-1.250	0.276	-3.232	-3.413	-3.288	-8.16
Factor1 x C_size[e]	.	-1.141	.	-1.096	.	0.144	.	3.174
Factor2 x C_size[f]	.	-1.485	.	-1.493	.	-3.344	.	3.112
Aerospace[b]	0.016	0.017	0.009	0.011	0.031	0.030	-0.007	-0.011
Financial services	0.028	0.031	0.020	0.023	0.040	0.034	0.039	0.029
Petroleum & chemical	0.002	0.002	0.006	0.006	0.015	0.015	-0.014	-0.013
Consumer products	0.084**	0.082**	0.090**	0.090**	0.050	0.051	-0.007	-0.004
Manufacturing	-0.013	-0.013	-0.028	-0.028	0.017	0.018	-0.002	-0.001
Pharmaceutical	0.162**	0.161**	0.166**	0.166**	0.190**	0.189**	0.165**	0.165
Industrial & automobile	-0.051+	-0.049+	-0.060+	-0.060+	-0.058	-0.057	-0.038	-0.036
Retailing & wholesale	0.023	0.024	0.013	0.017	0.043	0.043	0.014	0.012
Transportation	-0.032	-0.032	-0.019	-0.017	-0.024	-0.021	0.005	0.004
1988[c]	0.017	0.017	0.013	0.014	-0.002	-0.004	-0.042*	-0.044
1989	-0.009	-0.010	0.003	0.004	-0.040*	-0.041*	.	.
1990	0.002	0.0002	-0.047**	-0.048**	.	.	.	.
1991	-0.039*	-0.040*	.	.	.	.	.	.
F value	7.006**	4.772**	6.203**	5.551**	4.772**	4.285**	3.115**	2.825**
Adjusted R2	0.197	0.192	0.200	0.197	0.192	0.189	0.159	0.156
Number of Observations	460	460	353	353	253	253	168	168

[a]+p < 0.1. * p < 0.05. ** p<0.01. Dependent variables used in this table are one, two, three, four year lag ROI. [b]Industry categories are from Computerworld's Premier 100. Utility industry is the base industry (no dummy). [c]Year 1992 is used as the base year.

[d]The coefficient should be multiplied by e^{-10}. [e] [f]The coefficient should be multiplied by e^{-10}.

The models used in our analysis assume a non-linear relationship between IT investments and performance. We allowed for a saturation point (an inverse U-shaped relationship between performance and factor scores), beyond which the benefits of additional IT investments decrease (e.g., Demsetz & Lehn, 1985; McConnell & Servaes, 1990). Our results indicate a negative coefficient for some of the square terms, suggesting that the relationship between a firm's IT investments and performance may be non-linear and that a saturation point may exist. Prior studies have assumed that such a relationship, if one exists, is linear. These results have implications for managers who make IT investment decisions as well as researchers intent on studying the relationship between IT investments and performance.

References may be obtained from the authors, or, may be viewed on the Internet at:

http://dossantos.cbpa.louisville.edu/other/ais96ref.html