
Influence of information technology investment on firm productivity: a cross-sectional study

Subhasish Dasgupta
Joseph Sarkis and
Srinivas Talluri

The authors

Subhasish Dasgupta is Assistant Professor of Information Systems, Department of Information Systems and Sciences, College of Business Administration, Fairleigh Dickinson University, New Jersey, USA.

Joseph Sarkis is Assistant Professor of Operations Management, Graduate School of Management, Clark University, Worcester, Massachusetts, USA.

Srinivas Talluri is Assistant Professor of Production Management, Department of Information Systems and Sciences, College of Business Administration, Fairleigh Dickinson University, New Jersey, USA.

Keywords

Efficiency, Information systems, Information technology, Investment, Modelling, Productivity

Abstract

Impact of information technology on firm productivity has received significant attention in information systems literature. Although many studies were performed to investigate this effect, the results were not conclusive in supporting a systematic effect. This study investigates this phenomenon in both manufacturing and service industries by considering a sample of 85 manufacturing and 77 service firms. Our research methodology utilizes a combination of various data envelopment analysis models and non-parametric statistical techniques in testing for the influence of information technology investment on firm productivity. We investigate this effect under conditions of both constant and non-constant returns to scale assumptions. Our results provide some very interesting insights and recommendations.

1. Introduction

Recent advances in information technology have changed the way organizations work. Personal computers do the work done earlier by mainframes. Computers are networked together in organizations and users share programs, files and electronic messages. Telecommuting is on the rise with the ability to connect to organizational computer systems from home. The Internet has provided an environment in which information can travel across organizational and geographical boundaries. Although organizations are making increasing investments in information technology, the effect of such investments on firm productivity has been unclear.

The term "productivity paradox" has gained notoriety in the information systems circles. Although computing power has increased exponentially in the last three decades, yet productivity in firms, especially in the service sector, has stagnated (Brynjolfsson, 1993). Other studies have shown that information technology investment provides negligible benefits (Loveman, 1994). Since organizations are spending increasing amounts of capital on information technology, it is very important to understand the relationship between information technology investment and firm productivity. One such relationship is the determination of whether investment in information technology is increasing firm productivity.

This paper explores the effects of information technology investment on firm productivity in both manufacturing and service sectors. Our study investigates this phenomenon in both manufacturing and service industries by considering a sample of 85 manufacturing and 77 service firms. The research methodology utilizes a combination of various data envelopment analysis models and non-parametric statistical techniques in testing this effect under conditions of both constant and non-constant returns to scale assumptions.

2. Background

While the impact of information technology spending on firm performance has been studied for the past 20 years, findings of the studies have been inconclusive. While early research has been unable to find significant positive relationship between information technology spending and performance,

Brynjolfsson (1993) aptly stated that the “shortfall of evidence is not necessarily evidence of shortfall”, attributing the absence of evidence to mismeasurements of inputs and outputs.

A number of early studies did not document a significant impact of information technology spending and firm productivity or performance, giving credibility to the term: “productivity paradox.” Roach (1991) in a study of information workers from 1970 to 1986 found that computers had limited effect on the productivity of workers. In fact, some studies found a negative impact of information technology investment on productivity (Franke, 1987). Yet, more recent studies have found that information technology spending has a significant positive effect on intermediate measures of firm productivity and the return on investment (Hitt and Brynjolfsson, 1994; Brynjolfsson and Hitt, 1996). Information technology spending was also found to have a significant negative effect on the cost effectiveness of the firm (Alpar and Kim, 1990; Harris and Katz, 1991; Mitra and Chaya, 1996). Although most of these studies have investigated the effect of information system budgets in manufacturing firms, other studies that have considered service sector have not necessarily found similar results.

Recent studies have tried to extend the findings of the “productivity paradox” theory. Brynjolfsson and Hitt (1998) modified the traditional measures of productivity of information systems and proposed that productivity should be determined using organizational “value of information technology (or IT value)”. They defined IT value to include the tangible as well as intangible assets created by information technology investment. Brynjolfsson and Hitt argued against the existence of the “productivity paradox” by noting that information technology investment may create intangible assets which have a positive impact on the productivity of the firm. Grover *et al.* (1998) also emphasized the organizational role in information technology investment, by identifying the factors influencing investment priorities in organizations. In a study which did not consider overall information technology investment, but spending only in end-user computing related functions, Guimaraes (1997) found that such spending can increase company efficiency and effectiveness. Dewan and Kraemer (1998) investigated productivity of information technology

investment in 17 developed countries. Their study utilized a country-level of analysis and found that an increase in IT capital per worker is associated with an increase in GDP per worker, on average, but these results were not consistent among different countries. While recent studies have extended the productivity paradox theory, they have not addressed the basic issue of information systems spending and firm performance.

Most studies on information systems spending have been restricted to manufacturing firms (Barua *et al.*, 1991; Loveman, 1994; Morrison and Brendt, 1990). Moreover, of the studies that have examined the effect of information technology on firm productivity and output, only a few have investigated the effect on performance. Loveman (1994) in his research of 60 strategic business units found that the contribution of information technology capital to output was approximately zero for almost every sub-sample considered. Brynjolfsson and Hitt (1996) in their study of information systems spending from 1987 to 1991 indicate that spending has made a significant contribution to firm output, and that spending on information systems labor produces as much output as spending on non-information systems labor and expenses.

Studies have also investigated the effect of information technology on the cost structure. Mitra and Chaya (1996) found that information technology investments reduce average production costs, lower average total costs, and increase average overhead costs in firms. They did not have any evidence that information technology reduces labor costs in organizations. Mitra and Chaya also reported that larger companies spend more on information technology than smaller manufacturing firms.

Barua *et al.* (1991) investigated the effect of information technology spending on intermediate measures like capacity utilization, inventory turnover, quality, relative price and new product introduction. They found that spending was related to three out of the five measures, but these did not have a significant effect on overall performance measures for the firms. Morrison and Brendt (1990), using government reported data, found that information technology provided only marginal returns, and concluded that there was a general over-investment in information technology. In a study of technology investment and business performance, Rai *et al.* (1997)

decomposed information technology investment into capital, budget, client-server expenditure, information systems staff expenditure, hardware expenditure, software expenditure, and telecom expenditure. They reported that while all information technology components have a positive effect on firm outputs like value-added and sales, only information technology capital and client-server expenditure have a marginal positive effect on performance. Although Rai *et al.* (1997) considered both manufacturing and service industries, they did not report any difference between the two sectors.

Some studies have considered information systems spending and its effect on firm productivity in the service sector. In the banking sector a major share of information technology investment has been in the form of automated teller machines (ATMs). But, in a study of banks, Banker *et al.* (1990) found that there is no significant relationship between the number of ATMs owned by a bank and the number of local demand deposits and savings. These findings have extended to service functions within an organization. In a study of information workers, Roach (1991) found that there have been significant investments in information technology for information workers from 1970 to 1986. While production productivity grew by 16.9 percent during that period, information worker productivity decreased by 6.6 percent.

Although studies have been unable to determine significant positive impact of information systems spending on firm performance and productivity, cost-effectiveness of such investments have been reported in the literature. In a study of insurance companies, Harris and Katz (1991) found that high information technology spending is associated with lower growth in operating costs. Moreover, Bender (1986) reported that appropriate levels of information systems investments could have a positive effect on reducing operating expenses – the optimum level of investment for insurance companies studied was between 20 and 25 percent of total operating expenses. Information technology investments were also reported to decrease total costs in the banking industry (Alpar and Kim, 1990).

It is evident from our above discussions that there have been a significant number of studies in this area of productivity paradox. The accuracy and usefulness of any study of

this nature will heavily depend on the research methodology and data utilized. Our research presents a more robust methodology in testing for this effect in both manufacturing and service industries. We have also used very recent and comprehensive data sets of large companies in our study.

Thus far, studies in this area have been using traditional parametric techniques to investigate the impact of information technology investment on firm productivity. The primary limitation of these methods is that the data utilized must satisfy the underlying assumptions of normality, equal variance, etc. These constraining assumptions may culminate in biased results, which defeats the purpose of the study. To overcome these and other problems our research methodology utilizes more robust non-parametric techniques in testing for the same effect. Also, the models used in our study allow for simultaneous incorporation of multiple input and output measures, which is often difficult to do with traditional parametric methods.

One other dimension in which our study is more comprehensive than other related research is in considering both constant and non-constant returns to scale on information technology investments. We not only investigate the impact of these investments under conditions of linearity, but we also consider the fact that returns increase at a decreasing rate as the investment increases, which is non-constant returns to scale. Based on our above discussions, we strongly feel that our methodology provides improved and more accurate results in resolving the productivity paradox.

3. The hypotheses

Based on the above works, in this research we suggest that information technology investment will have a significant positive effect on firm performance for manufacturing firms. Therefore, we state our first hypothesis as follows:

Hypothesis 1: Increasing information technology investment has a positive impact on firm performance in the manufacturing sector.

Since information technology spending has a significant impact on reducing costs in the service sector, and costs directly affect the performance of the firm, we can state that information technology investment will have a

positive impact on the performance of firms in the service sector. Therefore, we believe that there is a propensity for productivity to increase from information technology investment in the service sector. Thus, we state our second hypothesis as follows:

Hypothesis 2: Increasing information technology investment has a positive impact on firm performance in the service sector.

The following sections provide a brief description to the methodological tools that are utilized in our study. In the next section we include three different DEA based models to help evaluate our hypotheses.

4. Models

4.1 The CCR model

Productivity models have traditionally been used to measure efficiency of systems. Typically, DEA productivity models for a given “decision-making unit (DMU)” use ratios based on the amount of output per given input. DEA allows for the simultaneous analysis of multiple inputs and multiple outputs. Using the notation of Doyle and Green (1994), the general efficiency measure that is used by DEA can best be summarized by:

$$E_{ks} = \frac{\sum_y O_{sy} V_{ky}}{\sum_x I_{sx} u_{kx}} \quad (1)$$

where:

E_{ks} is the efficiency or productivity measure of DMU s , using the weights of “test” DMU k , where the test DMU is the unit whose efficiency is to be evaluated;
 O_{sy} is the value of output y for DMU s ;
 I_{sx} is the value for input x of DMU s ;
 V_{ky} is the weight assigned to DMU k for output y ; and
 u_{kx} is the weight assigned to DMU k for input x .

For the basic DEA ratio model developed by Charnes *et al.* (1978) (CCR), the objective is to maximize the efficiency value of a test DMU k , from among a reference set of DMUs s , by selecting the optimal weights associated with the input and output measures. The maximum efficiencies are constrained to 1. The formulation is represented in equation (2).

$$\begin{aligned} &\text{maximise} && E_{kk} = \frac{\sum_y O_{ky} V_{ky}}{\sum_x I_{kx} u_{kx}} \\ &\text{subject to:} && \\ &&& E_{ks} \leq 1 \quad \forall \text{ DMU } s \\ &&& u_{kx}, V_{ky} \geq 0. \end{aligned} \quad (2)$$

This non-linear programming formulation (2) is equivalent to the following linear programming formulation (3):

$$\begin{aligned} &\text{maximise} && E_{kk} = \sum_y O_{ky} V_{ky} \\ &\text{subject to:} && \\ &&& E_{ks} \leq 1 \quad \forall \text{ DMU } s \\ &&& \sum_x I_{kx} u_{kx} = 1 \\ &&& u_{kx}, V_{ky} \geq 0. \end{aligned} \quad (3)$$

The transformation is completed by constraining the efficiency ratio denominator from (2) to a value of 1. This is represented by the constraint

$$\sum_x I_{kx} u_{kx} = 1.$$

The result of formulation (3) is an optimal “technical efficiency” value (E_{kk}^*) that is at most equal to 1. If $E_{kk}^* = 1$, then it means that no other DMU is more efficient than DMU k for its selected weights. That is, $E_{kk}^* = 1$ has DMU k on the optimal frontier and is not dominated by any other DMU. If $E_{kk}^* < 1$ then DMU k does not lie on the optimal frontier and there is at least one other DMU that is more efficient for the optimal set of weights determined by (3). The formulation (3) is executed s times, once for each DMU. Since the basic DEA model may provide a number of alternative DMUs that are efficient, it would be difficult for a decision-maker or organization to differentiate among multiple efficient DMUs, many of which occur when the basic CCR approach is used. To help discriminate among efficient DMUs and to help rank these DMUs, DEA ranking approaches may be used.

4.2 The BCC model

The linear programming formulation of the CCR model, shown as (3), assumes that outputs increase proportionally when inputs are increased, i.e. constant returns to scale. However, it is possible that the outputs may increase at a decreasing rate as the inputs are increased, i.e. decreasing returns to scale.

Banker *et al.* (1984) suggested a formulation that captures this phenomenon of variable returns to scale in DEA, which is referred to as the BCC model. The BCC model, represented below as (4), is the dual formulation of (3) with the added convexity constraint $\sum \lambda_s = 1$.

$$\begin{aligned} & \text{minimize} && E_{kk} \\ & \text{subject to:} && \\ & && \sum_s \lambda_s I_{sx} - E_{kk} I_{kx} \leq 0 \quad \forall x \\ & && \sum_s \lambda_s O_{sy} - O_{ky} \geq 0 \quad \forall y \\ & && \sum_s \lambda_s = 1 \\ & && \lambda_s \geq 0 \quad \forall s. \end{aligned} \tag{4}$$

4.3 A ranking (RCCR) model

A DEA approach that is helpful for ranking is a variation of the CCR model proposed by Andersen and Petersen (1993). In their model, they simply eliminate the test unit from the constraint set. The new formulation is represented by:

$$\begin{aligned} & \text{maximize} && E_{kk} = \sum_y O_{ky} V_{ky} \\ & \text{subject to:} && \\ & && E_{ks} \leq 1 \quad \forall \text{ DMU } s \neq k \\ & && \sum_x I_{kx} u_{kx} = 1 \\ & && u_{kx}, v_{ky} \geq 0. \end{aligned} \tag{5}$$

Equation (5), which we will call the “reduced” CCR (RCCR) formulation, allows for technically efficient scores to be greater than 1. This result will allow for a more discriminating set of scores for technically efficient units and can thus be used for ranking purposes.

5. Non-parametric statistical test

In this section, we provide some background on a non-parametric statistical test referred to as the Kruskal-Wallis (KW) test that is utilized to test our hypotheses (Conover, 1980). The KW test based on ranks is utilized to analyze the differences in two or more independent samples. This non-parametric test is used in our analysis because the efficiency scores obtained from the DEA models do not lend themselves to normality assumption as required by the parametric tests. The KW test is an extension to the Mann-Whitney test. While the Mann-Whitney test analyzes two samples, the KW test analyzes two or more

independent samples. The null and the alternate hypothesis for the test are:

H_0 : All of the k population distribution functions are identical

H_a : At least one of the populations tends to yield larger observations than at least one of the other populations

Test statistic:

$$T = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1) \tag{6}$$

where:

N is the total number of observations

k is the number of groups

n_i is the number of observations in i th group, where $i = 1$ through k , and

R_i is the sum of the ranks of observations in each group

Decision rule: if $T > \chi^2(k-1, 1-\alpha)$ then reject H_0 , otherwise fail to reject H_0 , where α is the probability of making a type I error.

To identify which groups are different, multiple comparisons can be conducted. The groups i and j are different if the following inequality is satisfied:

$$\left| \frac{R_i}{n_i} - \frac{R_j}{n_j} \right| > t_{1-(\alpha/2)} \left(S^2 \frac{N-1-T}{N-k} \right)^{1/2} \left(\frac{1}{n_i} + \frac{1}{n_j} \right)^{1/2}$$

where

$$S^2 = \frac{1}{N-1} \left(\sum_{\text{all ranks}} R(X_{ij})^2 - N \frac{(N+1)^2}{4} \right) \tag{7}$$

$R(X_{ij})$ is the rank assigned to observation j in i th group. t value is the $(1-\alpha/2)$ quantile of t distribution with $r-k$ degrees of freedom. The α value used is the same as in the KW test.

6. Research methodology

We utilized a sample of the largest companies in terms of information systems budgets, as reported in the *Information Week 500* (Violino, 1997). The companies reporting information systems budgets in *Information Week* were already classified into 20 different industries. We categorized these companies under manufacturing and service sectors. The manufacturing sector included the following industries: aerospace and engineering, chemicals, consumer goods, food and beverage, information technology, manufacturing, metals, and pharmaceuticals. The service sector included

banking, energy, financial services, healthcare, insurance, professional services, retail, telecommunications, transportation, and utilities. After dropping companies which had incomplete measures, our sample was reduced to 85 manufacturing and 77 service companies, in a total of 19 industries. Only one industry, media (service sector), had to be dropped from our analysis, since all companies in the industry had incomplete measures.

Our methodology considers information technology budget and information technology employees as the inputs to the DEA models and net income as the output. The manufacturing and service firms were evaluated separately to maintain a close observance to the DEA homogeneity recommendation for samples. A linear scale transformation is performed on net income in order to eliminate negative values, i.e. the maximum loss value is added to all the data points.

The CCR, BCC, and RCCR models are then utilized to evaluate the productivity of firms. While the CCR and BCC model results are evaluated under conditions of constant and non-constant returns to scale assumptions, respectively, the RCCR model is mainly utilized for ranking purpose only. In order to evaluate information technology investment impact on firm productivity, we statistically tested the DEA scores obtained from the CCR and BCC models by utilizing the KW test. The details of data splitting and testing procedures are explained in the results and discussion section.

7. Results and discussion

7.1 Manufacturing industry results

Of the 85 manufacturing firms considered in the analysis, the CCR model identified DMUs 24, 28, and 47 to be efficient with a relative efficiency score of 1.000, and the remaining 82 firms were inefficient with efficiency scores of less than 1.000. Based on these results one can conclude that the inefficient firms must either reduce their inputs (information technology budget and information technology employees) for the same level of output (net income) or increase their output for the same level of inputs.

The BCC model, which considers variable returns to scale, identified DMUs 1, 7, 24, 26, 28, 47, and 72 to be efficient. This model basically works under the assumption that net income does not increase proportionally to

increase in information technology budget and information technology employees. Finally, the RCCR model allows to differentiate among the efficient DMUs. Based on this model the CCR efficient DMUs 28, 24, and 47 with RCCR scores of 1.388, 1.277, and 1.008, respectively, can be ranked in that order. All the manufacturing sector results are depicted in Table I.

In order to evaluate information technology investment impact on firm productivity, we statistically tested the DEA scores obtained from the CCR and BCC models. Initially, the DEA scores are converted into ranks by assigning a rank of 1 to the maximum efficiency score, a rank of 2 to the next best score, and so on. The ties are appropriately considered by assigning mean ranks. The 85 firms are then ranked in the ascending order of investment, and split into three groups with approximately 33 per cent of the observations in each group. This split resulted in low, medium, and high investment groups of information technology spending. The KW test on the CCR scores rejected the null hypothesis ($\alpha = 0.05$) that all three groups have identical population distribution functions ($T = 43.50 > \chi^2 = 5.991$). We then performed multiple comparisons, shown in Table II, which indicated significant differences among firm productivity of all three groups. The results indicated that low investment group has the highest productivity followed by medium and high investment groups in that order.

The KW test on ranked BCC model scores also rejected the null hypothesis ($T = 18.47 > \chi^2 = 5.991$). The multiple comparisons, shown in Table II, indicated significant differences among low and medium, and low and high investments. The medium and high investment groups were not statistically significant, although the high investment group resulted in higher scores when compared to the medium group.

Our results in the manufacturing sector, in general, show that information technology investments have a negative effect on firm performance. This result supports earlier studies by Franke (1987), which suggested a negative relationship. A number of studies in the manufacturing sector, including those by Loveman (1994), Barua (1991) and Morrison and Brendt (1990), have not found any significant effect of information technology on overall firm performance.

Table I Manufacturing firm productivity scores

Company	CCR	BCC	RCCR	Company	CCR	BCC	RCCR
DMU1	0.295	1.000	0.295	DMU44	0.408	0.559	0.408
DMU2	0.073	0.080	0.073	DMU45	0.267	0.312	0.267
DMU3	0.110	0.119	0.110	DMU46	0.205	0.206	0.205
DMU4	0.133	0.152	0.133	DMU47	1.000	1.000	1.008
DMU5	0.227	0.250	0.227	DMU48	0.258	0.296	0.258
DMU6	0.070	0.072	0.070	DMU49	0.279	0.318	0.279
DMU7	0.343	1.000	0.343	DMU50	0.181	0.188	0.181
DMU8	0.220	0.226	0.220	DMU51	0.268	0.996	0.268
DMU9	0.153	0.275	0.153	DMU52	0.097	0.351	0.097
DMU10	0.066	0.181	0.066	DMU53	0.507	0.640	0.507
DMU11	0.351	0.355	0.351	DMU54	0.151	0.173	0.151
DMU12	0.072	0.134	0.072	DMU55	0.234	0.261	0.234
DMU13	0.251	0.292	0.251	DMU56	0.541	0.716	0.541
DMU14	0.230	0.280	0.230	DMU57	0.452	0.454	0.452
DMU15	0.072	0.239	0.072	DMU58	0.221	0.280	0.221
DMU16	0.247	0.314	0.247	DMU59	0.181	0.219	0.181
DMU17	0.373	0.475	0.373	DMU60	0.059	0.066	0.059
DMU18	0.253	0.259	0.253	DMU61	0.024	0.031	0.024
DMU19	0.144	0.163	0.144	DMU62	0.100	0.616	0.100
DMU20	0.085	0.306	0.085	DMU63	0.235	0.276	0.235
DMU21	0.179	0.189	0.179	DMU64	0.206	0.580	0.206
DMU22	0.374	0.485	0.374	DMU65	0.215	0.251	0.215
DMU23	0.190	0.246	0.190	DMU66	0.102	0.547	0.102
DMU24	1.000	1.000	1.277	DMU67	0.244	0.264	0.244
DMU25	0.182	0.236	0.182	DMU68	0.198	0.229	0.198
DMU26	0.720	1.000	0.720	DMU69	0.135	0.680	0.135
DMU27	0.834	0.924	0.834	DMU70	0.178	0.540	0.178
DMU28	1.000	1.000	1.388	DMU71	0.223	0.276	0.223
DMU29	0.143	0.173	0.143	DMU72	0.037	1.000	0.037
DMU30	0.480	0.530	0.480	DMU73	0.042	0.193	0.042
DMU31	0.169	0.196	0.169	DMU74	0.171	0.235	0.171
DMU32	0.301	0.528	0.301	DMU75	0.034	0.042	0.034
DMU33	0.244	0.317	0.244	DMU76	0.077	0.114	0.077
DMU34	0.492	0.519	0.492	DMU77	0.284	0.417	0.284
DMU35	0.705	0.952	0.705	DMU78	0.165	0.212	0.165
DMU36	0.697	0.867	0.697	DMU79	0.052	0.065	0.052
DMU37	0.348	0.378	0.348	DMU80	0.222	0.281	0.222
DMU38	0.416	0.417	0.416	DMU81	0.298	0.312	0.298
DMU39	0.235	0.320	0.235	DMU82	0.137	0.176	0.137
DMU40	0.070	0.079	0.070	DMU83	0.322	0.369	0.322
DMU41	0.035	0.036	0.035	DMU84	0.000	0.451	0.000
DMU42	0.051	0.055	0.051	DMU85	0.313	0.906	0.313
DMU43	0.078	0.086	0.078				

Table II Results of multiple comparisons based on the Kruskal-Wallis test

Population	CCR manufacturing	BCC manufacturing	CCR service	BCC service
Low and medium	24.4 > 9.30*	26.39 > 11.82*	–	16.03 > 11.89*
Low and high	42.04 > 9.06*	22.69 > 11.51*	–	14.71 > 12.01*
Medium and high	12.64 > 9.14*	3.7 < 11.62	–	0 < 12.01

Note: * indicates that the groups are significantly different at $\alpha = 0.05$. The entries in the Table represent the left-hand-side and right-hand-side values of equation (7)

7.2 Service industry results

A total of 77 service firms are analyzed in our study. The CCR model results identified DMUs 24 and 32 to be relatively efficient. The BCC model, which considers variable returns to scale, identified DMUs 24, 28, 32, 40, 43, and 57 to be efficient. The RCCR model ranked DMUs 24 and 32 as the best overall performers with productivity scores of 1.765 and 1.414, respectively. All the service sector results are depicted in Table III.

We statistically tested the ranked DEA scores obtained from the CCR and BCC

models. Similar to the manufacturing analysis, the 77 firms are ranked in the ascending order of investment, and split into three groups with approximately 33 per cent of the observations in each group. This split resulted in low, medium, and high investment groups of information technology spending. The KW test on the CCR scores failed to reject the null hypothesis ($\alpha = 0.05$) that all three groups have identical population distribution functions ($T = 4.61 < \chi^2 = 5.991$). It is for this reason that we did not perform any multiple comparisons. This result indicates that

Table III Service firm productivity scores

Company	CCR	BCC	RCCR	Company	CCR	BCC	RCCR
DMU1	0.185	0.197	0.185	DMU40	0.960	1.000	0.960
DMU2	0.202	0.209	0.202	DMU41	0.167	0.188	0.167
DMU3	0.216	0.243	0.216	DMU42	0.174	0.198	0.174
DMU4	0.393	0.394	0.393	DMU43	0.429	1.000	0.429
DMU5	0.238	0.413	0.238	DMU44	0.194	0.227	0.194
DMU6	0.230	0.248	0.230	DMU45	0.153	0.159	0.153
DMU7	0.382	0.417	0.382	DMU46	0.064	0.135	0.064
DMU8	0.239	0.240	0.239	DMU47	0.170	0.197	0.170
DMU9	0.311	0.333	0.311	DMU48	0.137	0.157	0.137
DMU10	0.140	0.152	0.140	DMU49	0.112	0.113	0.112
DMU11	0.326	0.332	0.326	DMU50	0.125	0.150	0.125
DMU12	0.134	0.135	0.134	DMU51	0.584	0.661	0.584
DMU13	0.213	0.225	0.213	DMU52	0.721	0.816	0.721
DMU14	0.197	0.224	0.197	DMU53	0.356	0.423	0.356
DMU15	0.247	0.275	0.247	DMU54	0.266	0.285	0.266
DMU16	0.130	0.140	0.130	DMU55	0.113	0.114	0.113
DMU17	0.049	0.052	0.049	DMU56	0.154	0.194	0.154
DMU18	0.469	0.496	0.469	DMU57	0.787	1.000	0.787
DMU19	0.113	0.118	0.113	DMU58	0.101	0.105	0.101
DMU20	0.306	0.310	0.306	DMU59	0.180	0.184	0.180
DMU21	0.353	0.472	0.353	DMU60	0.373	0.414	0.373
DMU22	0.064	0.069	0.064	DMU61	0.000	0.066	0.000
DMU23	0.388	0.441	0.388	DMU62	0.464	0.507	0.464
DMU24	1.000	1.000	1.765	DMU63	0.249	0.255	0.249
DMU25	0.109	0.118	0.109	DMU64	0.065	0.067	0.065
DMU26	0.047	0.125	0.047	DMU65	0.110	0.110	0.110
DMU27	0.231	0.293	0.231	DMU66	0.032	0.033	0.032
DMU28	0.446	1.000	0.446	DMU67	0.199	0.216	0.199
DMU29	0.209	0.258	0.209	DMU68	0.470	0.478	0.470
DMU30	0.586	0.629	0.586	DMU69	0.659	0.676	0.659
DMU31	0.143	0.144	0.143	DMU70	0.536	0.542	0.536
DMU32	1.000	1.000	1.414	DMU71	0.477	0.533	0.477
DMU33	0.107	0.111	0.107	DMU72	0.243	0.244	0.243
DMU34	0.575	0.675	0.575	DMU73	0.348	0.375	0.348
DMU35	0.126	0.168	0.126	DMU74	0.389	0.455	0.389
DMU36	0.505	0.548	0.505	DMU75	0.649	0.652	0.649
DMU37	0.303	0.367	0.303	DMU76	0.443	0.451	0.443
DMU38	0.180	0.204	0.180	DMU77	0.624	0.631	0.624
DMU39	0.072	0.079	0.072				

information technology investment has no effect on firm productivity in the service sector.

The KW test on ranked BCC model scores rejected the null hypothesis ($T = 7.22 > \chi^2 = 5.991$). The multiple comparisons, shown in Table II, indicated significant differences among low and medium, and low and high investments. The medium and high investment groups were not statistically significant.

Past studies in the service sector have shown that information technology investment has either no effect or a negative effect on firm performance (Harris and Katz, 1991; Roach, 1991). Although the CCR model results indicated no effect, the BCC model results demonstrated a negative effect on firm performance. Figure 1 depicts the relationship between information technology investment and productivity (sum rank scores of productivity). Based on Figure 1, we can conclude that, in general, there is a negative effect of IT investment on firm performance across manufacturing and service firms.

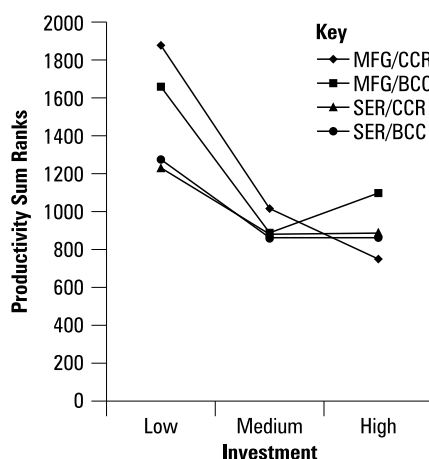
8. Conclusions

In conclusion, the results of our study provide some very interesting insights into the effect of information technology investment on firm performance. We have demonstrated using a relatively simple set of DEA models that productivity in the service and manufacturing sectors seem to lag as increased investment occurs. It does not seem to follow a pattern even though there does seem to be leveling off. Our research, in a way reconfirms the “productivity paradox” theory, which stated

that information technology has negligible or even a negative effect on firm performance. Moreover, the results of this study are contrary to recent findings, which have argued that productivity gains were not attained in past few decades, because restructuring and cost-cutting that are often necessary to realize the potential benefits of information systems were not undertaken by many firms (Brynjolfsson and Hitt, 1996). Since most firms have recently been involved in reengineering their processes, we expected that information technology investment will have a significant positive effect on performance, but our results proved otherwise. As a possible explanation of our results, we can say that as firms invest more in information technology there is a greater need for coordination between different activities and systems across all functional areas of the organization. This could be a possible reason for the negative impact of information technology investment on firm performance.

This work adds to the body of research evaluating the relationship between productivity and investment. Additional research can focus on specific types of information technology investment to help identify where organizations should be allocating their resources. Also, the output measures could be allowed to vary to determine not only strategic influences of information technology investment on productivity but more intermediate, operational and tactical performance impacts. Additional work focusing on a longitudinal data set may provide more insights into the productivity of organizations. A more reductionist approach to evaluating these relationships would include consideration of specific industry categories within the industry sectors. Finally, it would be interesting to investigate the effect of information technology investment on firm productivity using more advanced DEA models such as cone-ratios, cross-efficiencies and game formulations. In summary, we recommend additional research in this critical area of information technology investment and firm productivity.

Figure 1 Comparison of investment groups for manufacturing and service sectors



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