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Does successful investment in information technology solve the productivity paradox?

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Abstract

Based on previous empirical research, there seems to be little relation between investment in information technology (IT) and financial performance (often referred to as the 'productivity paradox'). We hypothesize that this is due to the fact that many companies implement IT projects ineffectively. Like any other asset, IT must be utilized effectively to result in increased financial performance. By comparing successful users of IT and less successful users of IT, we show that successful users of IT have superior financial performance relative to less successful users of IT. However, any financial performance advantage is short-lived, possibly due to the ability of competitors to copy IT projects.

Keywords: Productivity paradox; Information technology investment; Financial ratios; Financial performance; Competitive advantage

1. Introduction

In the eighties, information technology (IT) was heralded as a key to competitive advantage [10,33,39]. Porter and Millar [39] concluded that IT has affected competition in three ways: it has led to changes in industry structure and competition, it was used to support the creation of new businesses, and companies using IT outperformed their competition. The belief that IT can lead to a competitive advantage has become less certain in the nineties. Nevertheless, a high percentage of top executives still consider IT as a key to a company's profitability and survival [34].

In spite of theoretical arguments and professional belief in favor of a positive relation between investment in IT and superior financial performance, empirical evidence on this relation has been inconclusive. Several empirical studies and ample anecdotal evidence indicate that companies that spend more on IT are not rewarded with superior financial performance [5,16,28,46,47,51].

This study strives to find a better way to study the impact of using IT successfully on a company's financial performance. Our main proposition is that, ceteris paribus, successful users of IT should enjoy superior financial performance relative to less successful users of IT. The performance advantage should be observable when a company's financial performance is compared with that of similar companies in the same industry that have been less successful users of IT. We propose and test the impact of IT on financial performance by focusing on companies that have been recognized as successful users of IT because competitive advantage (and its corollary: relatively superior financial performance) rests on the firm's ability to

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manage IT related inputs in a more productive way [38].

Using non-parametric statistics, we test to see if there is any difference in the financial performance of successful users of IT and a carefully matched control group. The successful users of IT were chosen by independent experts in the field of IT, and the control group was matched on SIC code, sales and total assets. Performance was assessed using various measures of profitability and efficiency over a period of 10 years. Statistical analysis indicates that companies that have been identified as successful users of IT outperform their competitors in measures of profitability and efficiency. However, any financial performance advantage is short-lived, possibly due to the ability of competitors to copy IT projects.

2. Literature review

The seemingly obvious yet elusive relation between investment in IT and productivity, dubbed the 'productivity paradox', has been the center of numerous news articles, editorials, research projects and books [1,6–8,17,22,28,30,31,40,45–47,51]. Although the spectrum of these studies ranges from the role of investment in IT on the economy, industry, and at the firm-specific level, the latter is related to this study. For a detailed review of the literature on the productivity paradox, see [6–8,22].

In a series of articles and two books, Strassman [46,47] presents the results of his findings and the findings of several other studies. The conclusion he draws is that there is no identifiable association between expenditures on IT and profitability, and this relation has not changed for more than 20 years.

In his 1990 book, he presents the results of an analysis based on 292 companies. The scatter plot used to relate investment in IT and return on investment (ROI) reveals a random pattern. When he replicated his analysis using 1994 data for a group of 539 companies, the results were equally disappointing. The results do not change when he experiments with several different measures of profitability such as return on assets (ROA), return on net investment, and economic value added over equity. Segmenting his data set at the industry level did not improve the results. Strassman concludes that it is not how much you spend on IT, but how you manage your IT assets that makes the difference.

Weill [51] used data from the valve manufacturing industry to test the relation between investment in IT and firm performance, sales growth, ROA, and two measures of productivity. To better understand the impact of IT on performance, Weill categorized IT investment as strategic or transactional, depending upon the management's intention. Although transactional IT investment was found to be significantly associated with firms experiencing strong performance, strategic IT investment was found to be neutral in the long term, and associated with poorly performing companies in the short term.

Yosri [52] studied the relation between IT expenditures (operational, strategic and tactical), and revenue-contributing factors in 31 major food firms for the period of 1987–1990. Yosri found no significant correlation between IT investment and sales growth, market share gain, new market penetration, measures of quality improvement, and productivity.

Dos Santos et al. [16] find that an announcement of innovative IT has a positive effect on stock price. The announcement of non-innovative IT has a negative impact on stock price. Overall, announcements of investment in IT have no impact on stock price.

Loveman [30] used a microeconomic production function to estimate the impact of IT on productivity. Using sales minus change in inventory as a surrogate for output, and various non-IT expenditures, labor compensation, and IT capital as inputs, Loveman found that the output elasticity of IT was negative. This was interpreted as a suggestion to businesses that they are better off investing their marginal dollar in non-IT factors of production.

Barua et al. [5] used a process-oriented methodology to measure the impact of IT on strategic business units. Their main proposition is that the impact of investment in IT will be captured at low organizational levels by intermediate level variables (ex: inventory turnover). These variables in turn will impact output measures. Using data from the manufacturing sector for a period of 5 years, they found that IT indeed had a mostly favorable impact on intermediate variables. Intermediate variables were found to be significant determinants of high-level economic variables such as ROA and market share.

Hitt and Brynjolfsson [22] used a panel of 370 companies over the period 1988–1992, and tried to replicate previous studies to the degree that it was feasible. They examined the impact of IT spending on ROA, return on equity (ROE), and total shareholder return. Even after they introduced controls (firm-specific variables affecting profitability) to control for the possibility of spurious correlation, the results indicated no correlation between spending on IT, total shareholder return, ROA or ROE.

Mahmood et al. [31] used a 3-year, cross-sectional analysis (companies from *Computerworld's* Premier 100 (CWP100) list for the years 1991–1993) to compare the impact of IT investment from previous years with organizational performance and productivity of the following years. They used cluster analysis to classify firms based on their IT investments, performance and productivity. Their results suggest 'to some degree', a relation between investment in IT, performance and productivity. For the three sub-periods in their sample, they find a positive relation between IT investment and change in revenue growth. Results for the relation between IT investment and other measures of productivity and performance were not as clear.

3. Methodology

Investment in IT has been on an upward trend for the last 30 years. This upward trend can be seen in both relative and absolute terms; the former through the National Income and Product Accounts (NIPA) [49], and the latter from several extensive surveys by IT consulting firms.

Computers appear as a subcategory of the major components of the NIPA. More specifically, computer spending by companies is captured under the heading 'Producers Durable Equipment', which is a subcategory of 'Business Fixed Investment'. According to Haimowitz [21], real computer spending as a share of business fixed investment has risen from 2.12% in 1982–1986, to 13.11% in 1992–1996. Over the same two periods, the share of computer spending in terms of producers' durable goods has risen from 3.53 to 17.88%. The above percentages may underestimate the actual share, if you consider the fact that the definition of computers in the NIPA includes hardware but not software, unless the latter comes preloaded on the computer. According to Bakos [2], recent estimates raise the investment in IT to 30% of new capital investment.

According to a 1995 report of the Standish Group [43], "In the United States we spend more than $250 billion each year on IT application development." Strassmann [48] reports this figure to be $700 billion. Cap Gemini's 1998 Millennium Index study raised the year 2000 spending for Europe and the US to $850 billion [9]. Several studies have attempted to estimate the worldwide spending on IT. A 1998 study by the market research firm Killen & Associates [26] estimated worldwide spending on IT to be $1.59 trillion and projected this to be $2.62 trillion in 2002. *Computer Economics* [11] in their '1999 Information Systems and eBusiness Spending' report estimate the worldwide spending on IT for 2001 to be $1.1 trillion. All sources, drawing evidence from interviews and survey responses from company executives worldwide, agree that spending is not expected to slow down in the near future.

One would expect this investment to translate into improved financial performance; otherwise, the investment would seem irrational. As we have already seen, most of the empirical studies have concluded that either there is no relation between investment in IT and enhanced financial performance or at best there is a very weak positive relation.

We believe that the answer to this puzzle lies in the fact that the mere acquisition of an asset does not grant its owner a competitive advantage. What adds more validity to this argument is the fact that a significant percentage of the IT projects undertaken in any year have been failing to meet their objectives. The Genesys consulting group reports that over 80% of IT projects fail to deliver their anticipated benefits [20]. KPMG Peat Marwick [27] has coined these projects 'runaway projects'. The figures that are reported under the heading of 'Failure Record' in *The CHAOS Report* [43] are disturbing. According to the report, 31% of IT projects will be canceled before they are completed, and more than half will cost almost twice as much as originally estimated. Only 16% of software projects are completed on time and on budget. The problem with 'runaway projects' seems to be international. In a survey by KPMG UK, they report that 83% of the companies that they interviewed had experienced a runaway project [27].

In a recent report based on interviews with more than 1600 executives, the Meta Group claims "...that as much as $90 billion of the $700 billion it expects to be spent on Information Technology next year could be saved if users took more care in managing their relationships with vendors and services firms" [44]. Given this dismal record, it is not surprising that empirical studies show little or no relation between investment in IT and financial performance. If the distinction cannot be made between successful and unsuccessful users of IT, it is quite possible to observe no relation or a negative relation between investment in IT and financial performance. We use this simple yet powerful conclusion in our search to capture the elusive relation between IT and financial performance at the company level. Instead of trying to establish a relation between the level of investment in IT and financial performance, we suggest the possibility of superior financial performance for companies that have been recognized by IT experts as successful users of IT when compared to less successful users of IT.

We are proposing that, like any other asset, IT can be used effectively or ineffectively. Improved financial performance is the manifestation of how well the company is managing its IT assets. Effective users of IT assets should see a marked increase in financial performance compared to less successful users of IT assets.

Therefore, the null hypothesis that we are testing is

H_0. There is no difference in the distribution of financial performance measures of successful users of IT versus that of less successful users of IT.

Stated in the alternative form, it is

H_1. The financial performance of companies that have been recognized as successful users of IT is systematically better than that of less successful users of IT.

We stress the differential approach to establish the performance superiority between the two groups, because we do not want to give the false impression that IT will necessarily be associated with abnormal returns. Because computer-based information systems are easily copied by competitors, any financial performance advantage may be short-lived. Competitors will respond and attempt to neutralize the competitive advantage of the successful users of IT by copying and possibly improving the IT used. In some cases, a competitor's response may be almost immediate. For example, the World Wide Web has become the battleground in the overnight delivery service industry. FedEx was the first to use the Web with an on-line package tracking service in November 1994, followed by UPS 6 months later. In the March of 1996, UPS beat FedEx with complete Web shipping service. FedEx followed with a similar service in less than a year. This demonstrates how quickly competitors can respond to new IT [35,36,50]. MIT [32] predicted that, in the 1990's, IT would be a strategic necessity rather than a source of sustainable competitive advantage. This would result in short-term improvement in financial performance but no long-term differential performance advantage.

4. Dataset

The premise being tested is whether successful users of IT exhibit greater financial performance than less successful users of IT. The CWP100 list for 1993 was chosen to identify successful users of IT. By default, any company not appearing on the Premier 100 list is defined here as a less successful user of IT.

We are working with 1993 for the following reasons: first, this will give us a minimum of 5 years to study financial performance after the publication of the list. We believe that this is necessary, given the argument presented by David [13] and Mahmood et al. [31]. David [13] draws an analogy between cyberspace and the dynamo and argues that, as with the dynamo, the computer revolution will require a period of economic readjustment before the advances are reflected in the bottom line. Mahmood et al. [31] argue that there is a 2-year lag between the investment in IT and an improvement in financial performance. One explanation for observing the productivity paradox comprises researchers who have ignored this lag effect of investment in IT [2,7]. The second reason we used the year 1993 is that it is common knowledge that, for IT to be successful, it will have to be accompanied with significant re-engineering of the business process. According to a study from MIT [32], investment in new IT without parallel organizational change is unlikely to yield good results. Starting in the early nineties, more and more companies realized and started practicing this new mantra.

Since 1988, *Computerworld* has selected the 100 most successful users of IT. Each company is evaluated in terms of its performance according to four criteria: first, investment in IT as a percentage of revenues is used to determine a company's commitment to the new technology and its ability to be cost-effective. Second, 5-year growth rate in profits is used to establish business performance. Third, management is rated by establishing how well the information system of the company is positioned to service its business needs. Fourth, each company in the target group is asked to rank the five most effective users of IT in their industry. This fourth criterion, peer evaluation, carries double weight in the creation of the final weighted average score that is used for the ranking of the companies [12]. Starting in 1994, *Computerworld* changed its way of determining the companies that qualify for its Premier 100 list.

The dataset used in this study has several limitations. Because growth rate in profits is used as part of the score used to select companies for the CWP100 list (the successful firms), any financial performance ratios involving profitability may be biased in favor of finding a significant difference between the two groups. Likewise, the peer evaluation component of the CWP100 list likely contains firms that are outperforming their competition in a number of financial performance measures. This could lead to a possible bias toward rejecting the null hypothesis. These issues must be taken into account when considering the results of this study.

In order to be included in our study, companies had to have complete data on the Compustat database for the 10-year period examined, 1988–1997. This requirement eliminated 22 of the CWP100 companies. The methodology chosen to test the hypothesis in question is a matched pair design. The CWP100 companies were matched with the less successful users of IT (the control group) based on SIC code, total assets, and sales, for the year 1993. The variables to match on were chosen to control for industry, size, and capital intensity. Matching on these variables rules them out as alternative explanations for any difference found in financial performance between the two groups.

Where possible, the CWP100 companies were first matched with the control group by a four-digit SIC code. After selecting potential control group companies with complete data on Compustat for the period examined, the closest match based on total assets and sales was chosen as the corresponding firm for the CWP100 company. If a suitable competitor could not be found that was no more than twice as large or one half as small as the CWP100 company, matches were made at the three-digit SIC code level. Again, if a suitable match could not be made that was no more than twice as large or one half as small as the CWP100 company, matches were made at the two-digit SIC code level. Out of the 78 companies with complete data on Compustat, 44 were matched by the four-digit SIC code, 11 by the three-digit SIC code, and 16 were matched at the two-digit SIC code level. There were no matches for seven companies in the CWP100 list. This left 71 pairs of companies in the final study (see Table 1). Table 2 contains a list of all companies in the analysis.

Table 3 provides summary statistics for the two groups in terms of total assets and net sales. By design, both groups should have mean sales and total assets that are approximately equal.

Various financial performance variables are used to measure the relative performance of the two groups. These can be separated into two categories, profitability measures and efficiency measures. The profitability measures are growth in net sales, gross profit margin, operating profit margin, net profit margin, ROA, return on equity (ROE), and ROI. The efficiency measures are fixed assets turnover, total assets turnover, and inventory turnover. All data is from the PC Compustat database for the 10-year period

Table 1
Reconciliation of the original *Computerworld* Premier 100 (CWP100) companies and the 71 CWP100 companies in the study

CWP100 firms matched on a four-digit SIC code	44
CWP100 firms matched on a three-digit SIC code	11
CWP100 firms matched on a two-digit SIC code	16
Subtotal — total firm pairs	71
Number of unmatched CWP100 companies	7
CWP100 companies without full data on Compustat 1988–1997	22
Total — number of CWP100 companies	100

Table 2
The 71 *Computerworld* Premier 100 (CWP100) and 71 matched control group companies used in the study

S. No.	Experimental group (CWP100)	Control group
1	Abbott Laboratories	American Home Products Corp.
2	Air Products & Chemicals Inc.	Kerr-McGee Corp.
3	Airborne Freight Corp.	America West Hldg. Corp.
4	Albertsons Inc.	Great Atlantic & Pac Tea Co.
5	Alexander & Baldwin Inc.	Carnival Corp.
6	Allied Signal Inc.	United Technologies Corp.
7	Amerada Hess Corp.	Imperial Oil Ltd.
8	Banc One Corp.	First Union Corp.
9	Bandag Inc.	Continental Can/De
10	Bankers Trust Corp.	Morgan (JP) & Co.
11	Becton Dickinson & Co.	Medtronic Inc.
12	Browning-Ferris Industries	Westcoast Energy Inc.
13	Carolina Power & Light	GPU Inc.
14	Cigna Corp.	Aetna Inc.
15	Cone Mills Corp.	Guilford Mills Inc.
16	Crestar Financial Corp.	Summit Bancorp
17	Dillards Inc.	Harcourt General Inc.
18	Duke Energy Corp.	DTE Energy Co.
19	Dun & Bradstreet Corp.	Unisys Corp.
20	Engelhard Corp.	Allegheny Teledyne Inc.
21	FDX Corp.	US Airways Group Inc.
22	FMC Corp.	Hercules Inc.
23	Food Lion Inc.	Southland Corp.
24	FPL Group Inc.	Dominion Resources Inc.
25	Gencorp Inc.	Cordant Technologies Inc.
26	General Dynamics Corp.	McDermott Intl. Inc.
27	Goodrich (BF) Co.	Sequa Corp.
28	GTE Corp.	BellSouth Corp.
29	Harley-Davidson Inc.	Huffy Corp.
30	Harnischfeger Industries Inc.	Nacco Industries
31	Hershey Foods Corp.	Brown-Forman
32	Hon Industries	Lowes Cos.
33	Home Depot Inc.	Kimball International
34	Honeywell Inc.	Emerson Electric Co.
35	Hormel Foods Corp.	Dean Foods Co.
36	Intl Flavors & Fragrances	Lubrizol Corp.
37	Kellogg Co.	Ralston Purina Co.
38	Kellwood Co.	Leslie Fay Companies Inc.
39	Limited Inc.	Venator Group Inc.
40	McDonalds Corp.	ICH Corp.
41	MCI Communications	Sprint Corp.
42	Mellon Bank Corp.	Wachovia Corp.
43	Merck & Co.	Bristol Myers Squibb
44	Minnesota Mining & Mfg. Co.	Georgia-Pacific Group
45	Navistar International	Dana Corp.
46	Nortek Inc.	Griffon Corp.
47	Northeast Utilities	Central & South West Corp.
48	Northrop Grumman Corp.	Litton Industries Inc.
49	Oryx Energy Co.	Burlington Resources Inc.
50	Penney (JC) Co.	May Department Stores Co.
51	Phelps Dodge Corp.	Inco Ltd.
52	Polaroid Corp.	Bausch & Lomb Inc.
53	Quaker Oats Co.	Tyson Foods Inc.

Table 2
The 71 *Computerworld* Premier 100 (CWP100) and 71 matched control group companies used in the study

S. No.	Experimental group (CWP100)	Control group
54	Raychem Corp.	National Service Industries Inc.
55	Raytheon Co.	Baxter International Inc.
56	Readers Digest Association	McGraw-Hill Companies
57	Rohm & Haas Co.	Arco Chemical Co.
58	Rubbermaid Inc.	Armstrong World Industries Inc.
59	Schering-Plough	Pharmacia & Upjohn Inc.
60	Sherwin-Williams Co.	Olin Corp.
61	Tecumseh Products Co.	United Dominion Industries
62	Textron Inc.	Tenneco Inc.
63	Travelers Group Inc.	Morgan Stanley Dean Witter & Co.
64	US West Inc.	Ameritech Corp.
65	UAL Corp.	Delta Air Lines Inc.
66	Union Pacific Corp.	CSX Corp.
67	UNOCAL Corp.	Occidental Petroleum Corp.
68	Wal-Mart Stores	K Mart Corp.
69	Westvaco Corp.	Union Camp Corp.
70	Whitman Corp.	Coors (Adolph)
71	Willamette Industries	Bowater Inc.

1988–1997. For an explanation of how each ratio was calculated and interpreted as a measure of financial performance, see Table 4.

There is an extensive body of literature on the distributional properties of financial accounting ratios. For a thorough review of the literature on financial ratios, see Salmi and Martikainen [41] and Foster [18]. There is agreement among researchers that the distributions are characterized by non-normality, skewness (primarily right skewed), fat tails, and a significant number of outliers [3,4,14,19,24]. Distributions with fat tails (leptokurtic or cauchy distributions) are particularly problematic when using parametric statistics [25].

Table 5 provides summary statistics of the variables considered for all 142 companies in the sample for 1993. Foster [18] explains the existence of outliers in distributions of financial ratios in terms of accounting, economic and technical reasons. As expected, there are a significant number of outliers. The interquartile range can be used as an aid to confirm the existence of outliers. A simple rule of thumb states that we call an observation a possible outlier if it falls more than 1.5-times the interquartile range above the third quartile or below the first quartile. The results were similar for every year in the data set.

Given the nature of the proposition to be tested, difference variables were created for each pair of

Table 3
Comparative statistics (for 1993)[a]

	N	Mean	Standard deviation	Min	Max
Total assets					
CWP100	71	11560	20815	352	101360
Control	71	11914	23510	270	133888
Total	142	11737	22125	270	133888
Sales					
CWP100	71	6263	8627	590	67345
Control	71	5524	5681	437	34353
Total	142	5894	7288	437	67345

[a] Dollar amounts are in millions.

Table 4
Financial performance variables

Ratio	Calculation	Interpretation
Profitability measures		
Growth in net sales	Net sales for the current period minus net sales from the prior period divided by net sales from the prior period	Measures a company's growth in net sales over the prior year
Gross profit margin	Gross profit divided by net sales	Percentage of gross profit per dollar of sales
Operating profit margin	Income from operations divided by net sales	Measures income from operating activities per dollar of sales
Net profit margin	Income from continuing operations divided by net sales	Measures income from ongoing operations per dollar of sales
Return on assets	Income available to common shareholders from continuing operations divided by average total assets	Measures profitability and how efficiently assets were employed during the period
Return on equity	Income available to common shareholders from continuing operations divided by common shareholder's equity	Measures the profitability of the investment to the owners
Return on investment	Income available to common shareholders from continuing operations divided by total invested capital	Measures the profitability of the investment based on total investment, both debt and equity
Efficiency measures		
Fixed assets turnover	Net sales divided by average property, plant and equipment	Measures management's ability to generate sales, given an investment in fixed assets
Total assets turnover	Net sales divided by average total assets	Measures how efficiently management utilized assets to generate sales
Inventory turnover	Cost of goods sold divided by average inventory	Measures the liquidity of inventory and how quickly inventory is sold

Table 5
Summary statistics (for 1993)

Variable	Min	Q_1	Median	Q_3	Max	Mean	Standard deviation
Growth in net sales	−53.20	−1.20	4.45	8.90	95.50	4.27	13.60
Gross profit margin	2.16	22.33	30.74	44.78	81.99	34.72	17.80
Operating profit margin	−11.30	5.33	9.75	16.78	67.80	11.75	9.97
Net profit margin	−14.39	2.10	4.65	8.66	27.78	5.70	6.67
Return on assets	−21.90	1.28	3.52	7.07	19.82	4.39	5.83
Return on equity	−160.68	5.62	13.27	19.08	142.23	11.95	25.19
Return on investment	−479.93	3.33	6.99	12.28	46.76	4.66	42.16
Fixed assets turnover	0.32	1.55	3.34	5.24	19.63	3.92	3.21
Total assets turnover	0.06	0.62	1.02	1.41	3.62	1.09	0.70
Inventory turnover	0.08	3.96	6.16	9.29	131.11	11.50	18.42

matched companies. Subtracting the financial performance measure of the less successful company (control group) from the successful company (CWP100) for each year created the difference variables. Positive values for the differential measures of profitability and efficiency speak in favor of our hypothesis. Table 6 reports summary statistics of the difference variables for the 71 pairs of companies in the sample for 1993.

Given the nature of the underlying data set and the proposition to be tested, it may be deceiving to look at measures of central tendency. However, we can still get a glimpse at the results by looking at the means and medians of the distributions. The *t*-tests for testing if the population mean is different from 0 is significant in most cases, but may not be reliable due to the underlying distributions of the variables. Although the sample is large enough to justify the use of the central limit theorem, and it may be possible to compensate for the existence of outliers, we believe that this type of testing will not capture the true nature of our proposition. To test whether the financial performance of companies that have been recognized as successful users of IT is systematically better than that of less successful users of IT, non-parametric statistics will be used. We refrain from testing weather the median of differences is 0 because it implies the assumption of a distribution that is continuous and symmetric [23,29]. We have already seen that the distribution of financial ratios tends to be skewed. The non-parametric test is the Wilkoxon signed rank test for matched pairs, the recommended test in cases of paired data where the normality of the data is questionable [29]. Table 7 reports the *p*-values for the Wilkoxon test. Lower *p*-values indicate stronger sample evidence in favor of rejecting the null hypothesis.

Table 6
Difference variables (for 1993) — summary statistics

Difference in:	Count	Min	Q_1	Median	Q_3	Max	Mean	Standard deviation
Growth in net sales	71	−89.40	−3.30	2.60	8.30	57.10	1.05	16.96
Gross profit margin	71	−37.53	−4.53	1.56	9.73	35.34	2.33	14.49
Operating profit margin	71	−36.80	−2.90	2.30	6.50	17.60	1.68	9.43
Net profit margin	71	−29.04	−2.52	1.49	5.42	17.35	1.06	7.62
Return on assets	71	−12.73	−1.25	2.05	5.26	27.47	2.64	6.65
Return on equity	71	−130.87	−4.53	1.73	13.97	172.82	2.72	31.56
Return on investment	71	−22.52	−2.29	3.05	11.14	487.68	11.07	12.87
Fixed assets turnover	68	−5.07	−0.38	0.18	0.99	7.45	0.33	2.32
Total assets turnover	71	−0.68	−0.07	0.04	0.30	0.98	0.10	0.31
Inventory turnover	65	−86.48	−1.57	0.78	2.42	86.05	0.84	21.85

Table 7
Hypothesis testing: p-values for H_0[a]

Measure	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	No. of years ($p \leq 0.05$)[b]
Growth in net sales	*0.08*	0.76	*0.61*	0.44	**0.00**	0.06	**0.01**	*0.77*	**0.03**	0.10	3
Gross profit margin	*0.50*	0.97	0.89	0.47	0.30	0.13	0.21	*0.98*	0.69	1.00	0
Operating profit margin	*0.92*	0.80	0.41	0.23	**0.02**	**0.02**	**0.02**	0.45	0.38	0.71	3
Net profit margin	*0.62*	0.09	**0.05**	**0.02**	**0.00**	0.06	**0.01**	0.20	*0.90*	*0.65*	4
Return on assets	0.10	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	0.24	0.46	7
Return on equity	*0.39*	0.19	**0.02**	**0.01**	**0.00**	**0.05**	**0.01**	0.26	0.10	*0.10*	5
Return on investment	0.15	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	0.07	0.15	*0.81*	6
Fixed assets turnover	*0.72*	*0.32*	*0.27*	0.38	0.36	0.16	0.37	0.34	0.41	*0.57*	0
Total assets turnover	**0.03**	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**	**0.00**	**0.01**	0.13	0.07	8
Inventory turnover	*0.58*	*0.50*	0.27	0.17	0.11	0.30	0.16	0.07	*0.11*	*0.55*	0

[a] p-values in 'bold' are significant at the 5% level (two-tailed test); 'italics' indicate instances where the control group performed better.
[b] The mean is 3.6 years; the median is 3.5 years.

Although previous empirical studies have been unable to demonstrate the existence of a positive correlation between investment in IT and financial performance, this should not be interpreted as a reason to consider investments in IT as worthless. As our results demonstrate, there is a systematic difference in the financial performance of successful users of IT and less successful users of IT.

Although we are using the CWP100 list for 1993, we expect that these companies have been successful users of IT for a number of years. Peer evaluation comprises 40% of the weighted average score to appear on the Premier 100 list, and it likely takes a few years to establish a reputation within a peer group. Therefore, we expect to see a difference in the financial performance between the two groups before 1993.

We predict that growth in net sales will be larger for the successful users of IT than for the less successful users of IT. This difference is significant ($p \leq 0.05$) in 1992, 1994, and 1996, clearly supporting our proposition. It has been argued that successful users of IT should outperform less successful users of IT in profitability measures such as gross profit margin, operating profit margin and net profit margin. Our results support this argument. For gross profit margin, the p-values decrease as we approach 1992–1993 and increase subsequently, but the sample evidence is not strong enough to lead to the rejection of the null hypothesis (in 1993, $p=0.13$). For operating profit margin, the difference is significant ($p=0.02$) in the years 1992–1994, but not before or after this period. The difference in net profit margin tells a similar story. The difference is significant as early as 1990 ($p=0.05$), and remains significant until 1994, except in 1993 ($p=0.06$).

The three return measures, ROA, ROE, and ROI, all support our hypothesis. For ROA, the difference is significant in 1989, and remains significant through 1995. For ROE, the difference is significant in 1990 and remains significant until 1994. The difference in ROI is significant in 1989–1994, 1 year after the publication of the Premier 100 list.

The three efficiency measures examined were fixed assets turnover, total assets turnover and inventory turnover. The only efficiency measure that significantly supports our hypothesis is total assets turnover. The difference in total assets turnover is significant in the first 8 years examined, but not significant in 1996 and 1997. The p-values for fixed assets turnover and inventory turnover decrease when approaching 1992–1993 and increase subsequently, but the sample evidence is not strong enough to lead to the rejection of the null hypothesis.

As expected, the relative difference in performance starts before 1993, the year of publication of the list. Companies in the list have been recognized by their peers for their superior use of IT. Naturally, the IT they have implemented and how it was implemented are scrutinized, replicated, and improved by their competitors. The recognition of superior use of IT carries the seed of its own destruction. Any differences in performance will disappear shortly after recognition because competitors will respond by copying IT systems that have a proven record of success. The empirical evidence presented here clearly supports this argument. We observe that the p-values start rising (the differences becoming less significant) shortly after the year of publication. Looking at the duration of the statistically significant superior performance, we see that it usually ranges for 3–4 years (mean=3.6 years, median=3.5 years).

5. Conclusions

According to the proponents of the productivity paradox, its manifestation becomes apparent in the lack of any statistically significant correlation between investment in IT and gains in productivity. Logically, one would expect that companies that invest heavily in IT should be rewarded with superior financial performance. As mentioned in our literature review, empirical evidence in favor of a positive association between investment in IT and financial performance is anemic.

Brynjolfsson [6] proposes four non-exclusive explanations for the productivity paradox: mismeasurement of inputs and outputs, lags due to learning and adjustment, mismanagement of information and technology, and redistribution and dissipation of profits. Brynjolfsson attributes the measurement error to the difficulty of developing accurate, quality-adjusted price deflators. He argues that improvements in product quality and the introduction of new products need to be properly accounted for in the value of output.

Lags as an explanation of the paradox suggest that the benefits associated with investments in IT may take several years before they 'show (up) in the bottom line'. This is due to a period of learning associated with adjustment and possibly restructuring of the organization caused by new IT. The third proposition, 'mismanagement of information and technology', suggests that IT is not productive, and managers who choose to invest in IT are not acting in the best interests of the company. Finally, redistribution as an explanation of the productivity paradox argues that 'IT rearranges the shares of the pie' in favor of some companies 'without making it any bigger'.

Bakos [2] offers an alternative list of possible explanations for the productivity paradox, listing mismeasurement, mismanagement, diffusion delay, and capital stock theory as the four 'prominent hypotheses' for the explanation of the paradox. Although diffusion delay is another name for Brynjolfsson's lags, he replaced 'redistribution' with Oliner and Sichel's 'capital stock theory' [37]. According to Oliner and Sichel, in spite of the recent spending in IT, IT's share of capital stock is still small. This is because firms have only recently started investing heavily in IT, and by nature, IT tends to rapidly become obsolete. This makes it difficult for researchers to observe the impact of investment in IT on financial performance.

Brynjolfsson and Hitt [7] considered and empirically tested the possibility of the productivity paradox as 'an artifact of mismeasurement'. They used the neoclassical production theory in order to determine the contribution of such inputs as computer capital and information systems staff labor to output. They measured output in inflation-adjusted dollar terms because, according to the authors, this partially accounts for changes in product quality and introduction of new products. The authors conclude that "our results indicate that IS have made a substantial and statistically significant contribution to firm output," and that the productivity paradox "disappeared by 1991, at least in our sample of firms." By focusing on one of the four possible explanations (mismeasurement) for the productivity paradox, Brynjolfsson and Hitt [7] were able to show a significant relation between investment in information systems and firm output.

In all likelihood, the productivity paradox is due to a combination of factors, as suggested by Brynjolfsson [6] and Bakos [2]. Our research considers the possibility that a portion of the productivity paradox is attributable to mismanagement. Schrage [42] describes a rather colorful variation of the productivity paradox. He says that companies have wasted billions of dollars "believing the big lie of the Information Age." According to Schrage, the spending spree on IT was justified by a "beautiful hypothesis" that companies that had more and better information could improve their financial performance and competitive position. The hypothesis was slew, according to Schrage, by an "ugly fact" that managers had acted irresponsibly in relying on technology to solve fundamental problems. Recent empirical findings of Strassmann [47,48] indicate that the lack of any significant correlation between the investment in IT and performance points to possible irrational behavior of the management.

What Schrage calls a "beautiful hypothesis" was developed over the years and was based on several studies (e.g. [33,39]), suggesting that IT could be a source of competitive advantage.[1] It can be argued that companies responding to these propositions and ample anecdotal evidence joined the IT bandwagon and invested ever-increasing amounts in IT. As shown earlier, the latter can be seen in both growth rates and in absolute terms.

Unfortunately, not all of this investment was successful. Investment in IT at the early stages spread like an epidemic (it was considered a panacea) and naturally did not deliver the unrealistically expected results. What is disconcerting is the fact that, in more recent years, in spite of the sensitivity and awareness of company CFOs regarding the amounts spent unsuccessfully on IT, which resulted in more careful justification of IT projects, the situation has not improved. The majority of IT projects continue to fail. Recent developments indicate that this trend may continue because it is fed by the e-commerce revolution. As long as companies are rushing to jump indiscriminately on the e-commerce bandwagon, we are bound to see more and more of these investments fail. As mentioned earlier, according to the 1995 Chaos Report [43], well over 80% of IT projects fail, either because they cannot deliver the desired results or because they encounter significant overruns in terms of spending and/or time needed for completion.

Naturally, if you combine these two factors, high investment in IT and high failure rate in IT projects, you should not expect to find any positive correlation between amount invested and performance. Any correlation will be obscured by the high percentage of the amount invested that fails to have any positive impact on the performance of the company. The correlation will continue to be insignificant even when controlling for such factors as industry, nature of investment in IT etc. [47,48].

The combination of increasing investment in IT and a high failure rate for IT projects is another way to express Brynjolfsson's [6] and Bakos' [2] concept of mismanagement. The natural corollary of this explanation is in the form of a proposition. If you could control for mismanagement, would you expect to observe a statistically significant positive correlation between investment in IT and financial performance? Several studies point to the fact that this will not be enough because IT is not an isolated island within the organization (e.g. [47,48]). The sheer completion of a project on time, on budget and with the required specification is not enough to lead to superior financial performance. Many companies might invest in the same technology, but only those who manage to successfully integrate the IT into their business processes will be able to add value to the company. According to Porter and Millar [39], IT is the conduit that links the processes within an organization and adds value to the company. Therefore, superior financial performance will only be the reward of companies who have not simply completed IT projects but have successfully integrated IT into their business processes. One reason why we find a financial performance advantage is that the CWP100 companies are specifically evaluated based on how well the information system of the company is positioned to service its business needs.

Our contribution is in terms of empirically testing and validating the proposition that mismanagement is another viable explanation for the productivity paradox. Using a quasi-experimental design allows us to examine to what extent companies that have been recognized by industry experts and their peers as successful users of IT will experience statistically significant performance advantage relative to their competitors. The empirical results provide statistical support for our argument that successful investment in IT leads to superior financial performance.

6. Limitations and suggestions for further research

The issue of causality is problematic in a quasi-experimental design where the experimental and control groups are not randomly assigned. Consider the three classical requirements of causality, a significant correlation between variables, a temporal ordering of events, and the ruling out of alternative explanations. In this study, we show the correlation between successful investment in IT and financial performance. Using a matched pair design controls for alternative explanations such as the effects of industry, size, and capital intensity.

The temporal ordering of events is unclear. We argue that successful use of IT leads to improved financial performance, but it is possible that improved financial performance leads to successful use of IT. The logical sequence seems to be the former, but we have not ruled out the latter. The data in Table 7 show that the CWP100 companies started outperforming the control group years before appearing on the CWP100 list in 1993. We argue that this is because these companies were probably successful users of IT before 1993. We do not argue that the CWP100 companies became successful users of IT in 1993, and were previously not successful users of IT. Peer evaluation is a major component of the score used to compile the list. It likely takes a number of years to develop a reputation as a successful user of IT within your peer group, and therefore, companies appearing on the list have probably been successful users of IT for a number of years. A logical follow-up study would be to examine a small subset of firms on a case-by-case basis to try to identify the temporal ordering of financial performance and successful use of IT.

An additional area for future research is to examine other explanations for the productivity paradox. Bakos [2] gives four possible explanations for the productivity paradox viz. mismeasurement, mismanagement, diffusion delay, and the capital stock theory. In order to truly understand the productivity paradox, each explanation should be tested independently, and then together. Brynjolfsson and Hitt [7] addressed mismeasurement, and in this paper, we address mismanagement. Future research could focus on diffusion delay and the capital stock theory.

7. Summary

Several empirical studies have had difficulty relating investment in IT and financial performance. This is often referred to as the productivity paradox. In this paper, we address this question using a quasi-experimental design comparing successful users of IT with less successful users of IT. This focus on successful use of IT was primarily to assess mismanagement as a possible explanation for the productivity paradox. Examining 10 financial performance measures over 10 years, we find that, in general, successful users of IT outperform less successful users of IT for 3–4 years. It appears from our results, taken in the light of previous studies, that how you manage your IT assets is more important than how much you spend on IT. We expect that any performance advantage of the effective users of IT will tend to erode with time as competitors copy their IT investment and implementation.

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