IMPLEMENTATION OF KNOWLEDGE MANAGEMENT SYSTEMS AND FIRM PERFORMANCE: AN EMPIRICAL INVESTIGATION

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ABSTRACT

This study examines the impacts of adopting knowledge management systems (KMS) on firm performance. Although many organizations have implemented KMS, sparse empirical evidence reveals the impacts of KMS on firm performance. This research attempts to analyze the impacts of KMS on the firms that adopt KMS with the data extracted from the COMPUSTAT. The results indicate that these firms significantly reduce administrative costs and improve productivity in the second year after adopting KMS. To control the macroeconomic effects, the study also compares the financial performance of KMS adopters and non-adopters in a pairwise design. Furthermore, pertaining to cost and profit ratios, significant differences arise because the financial performance of non-adopters decreases over time while it holds steady for adopters. The findings verify some of our hypotheses, provide new insights into the productivity paradox associated with KMS adopters, and confirm that KMS adopters indeed gain a competitive advantage over non-adopters.

Keywords: Knowledge management, knowledge management system, firm performance

INTRODUCTION

Over the past few years, given the growing interest in treating knowledge as a significant organizational resource, organizational knowledge and knowledge management (KM) in particular, IS researchers have commenced promoting a class of information systems, referred to as knowledge management systems (KMS). The objective of KMS is to support the creation, transfer, and application of knowledge in organizations (1). Given that IS researchers and practitioners often debate over the contribution of IT investment to firm performance, this study focuses on KMS and its impacts on firm performance. KMS is employed to reduce costs by improving efficiency and effectiveness through computerization as well as to enhance decision making by providing accurate and timely enterprise-wide knowledge from the knowledge repository. These effects of adopting KMS for firms may be associated with improved firm performance. A review of the literature reveals a dearth of empirical research on how to successfully develop and implement KM solutions to enhance firm performance, particularly in core business processes (35, 36). Nowadays, much of the current KM research focuses either on the use of various technologies to acquire or store knowledge resources (1) or on the conceptual nature of KM (5, 7).

In the field of KMS study, most analyses accentuate the technical aspects, but exiguous research concentrates on how these systems actually improve the bottom line in the organizations. It remains uninvestigated whether or not adopting KMS can improve organization performance. Hence, from an empirical perspective, this study attempts to analyze the impacts of KMS on the firms that adopt the system. We carefully select the qualified KMS vendors from KM World Magazine, which, in its March 2003 issue, lists KM World's 100 companies that provide different kinds of knowledge management applications. We identify KM vendors' client companies that have acquired their KM solutions and extracted their financial data from the COMPUSTAT. To control the macroeconomic effects, we create a matching set of control firms drawn from the COMPUSTAT. Similar methodologies have been employed in previous studies of firm performance (3, 8, 28).

Furthermore, the resource-based theory and transaction cost theory explicitly recognize the importance of intangible capability such as organizational knowledge assets; these two theories provide significant theoretical complementarities for examining the relationship between KM capability and firm performance. The remainder of this paper is organized as follows. The introductory section reviews KMS and its capability with the resource-based theory and the transaction cost theory. The literature review foregrounds the theoretical foundations of this research, which propose hypotheses in the following section. The third section presents the methodological components: data collection and empirical analysis in the research method. The conclusion draws the findings along with some implications and suggestions for the directions of future research.

LITERATURE REVIEW

Knowledge Management System

KM requires a commitment to create new task-related knowledge, disseminate it throughout the organization, and embody it in products, services, and systems (39). The definition of knowledge is that systems designed to support knowledge in organizations may not appear radically different from other forms of information systems, but will be geared toward enabling users to assign meaning to information and to capture some of their knowledge in information and/or data (1). IT is

critical to KM as technologies such as groupware and multimedia systems that assist in clarifying assumptions, speeding up communications, eliciting tacit knowledge, and constructing histories of insights and cataloging them (8, 18, 22). Embedding knowledge in such systems enables its rapid transfer to novices and other new members. For example, Hughes Space and Communications has built a "lessons learned" database that captures the unstructured knowledge of its design team in the form of wisdom, experience, and stories. The database aids in the design of new satellites by providing access to reports of past defects. While other firms can make similar investments, they would be hard-pressed to emulate the structure for categorizing and searching the knowledge bases and to sustain the level of ongoing support needed for the maintenance of knowledge bases (14).

Housel and Bell (2000) pointed out KM services may include customer relationship management (CRM) services, business intelligence services and enterprise information portals (27). KMS are IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage, retrieval, transfer, and application. With the growing strategic importance of KM and KMS in organizations, more firms have adopted KMS (1, 14, 30, 33). In a nutshell, KMS can be defined as a class of information systems applied to manage organizational knowledge and include CRM, business intelligence services, and document management systems.

Resource-based Theory and KM Capability

Rooted in management strategy literature, the resource-based view (RBV) of the firm posits that firms compete on the basis of "unique" corporate resources that are valuable, rare, difficult to imitate, and non-substitutable by other resources (44). The RBV operates under the assumptions that the resources needed to conceive, choose, and implement strategies that are heterogeneously distributed across businesses and that these business differences remain stable over time (4). Although proponents of the RBV generally tend to define resources broadly to include assets, knowledge, capabilities, and organizational processes, Grant (1995) distinguishes between resources and capabilities and provides a classification of resources into tangible, intangible, and personnel-based resources (21).

Adopting the RBV, IS researchers identified various IT related resources that serve as potential sources of competitive advantage (8, 43). Bose (2002) describes the various technical elements required for KM and provides a technological framework for KM capability (9). Extending the traditional notion of organizational capabilities to a firm's IT function, a firm's KM capability is defined in this study as its ability to adopt and deploy KMS in combination with other kinds of information system and resources. Specifically, the concept of KM capability is developed using the premise that while resources can be easily duplicated, a unique set of capabilities mobilized by a firm cannot be easily duplicated and will result in sustained competitive advantages and better firm performance. Viewed from RBV, the KMS provides the resources that make feasible innovation and continuous improvement of firms' KM capability. In summary, the RBV illustrates that firms can differentiate themselves on the basis of their KMS. While each of the individual knowledge assets is complex to acquire and difficult to imitate, firms that achieve competitive advantage through KMS have also learned to combine their knowledge assets to effectively create an overall KM capability.

Transaction Cost Theory and KM Capability

To a certain extent, the transaction cost theory and resource-based theory are complementary. From the stance of theoretical pluralism, the two theories offer more comprehensive perspective by taking both costs and benefits into account (40, 50). RBV compensates for the weakness of transaction cost theory by looking at the value-creating benefits of a transaction (50). Transaction cost economics proposes that a firm is an economic entity created in an effort to economize on market transaction costs — searching and communicating market information, negotiating a deal, and preventing or dealing with contract default (24, 41). External sourcing of an input factor may entail extra costs in obtaining market information, communicating with geographically separated vendors, transporting goods, and holding inventories (24). Market transaction costs may be classified into two categories: one is due to the loss of operational efficiencies, while the other is establishing and maintaining contractual relationship with outside parties (41).

For the transaction cost theory, the KMS is expected to maintain an accurate knowledge repository as more accessible, which reduces administrative, search, and decision-making costs. Because of the practical difficulties involved in allocating buying costs, storage costs, and handling costs, these items are not ordinarily included in valuing inventories or product costs, but are period expenses (31). These costs are also reflected in the general and administrative categories of the financial statement. Much empirical research has supported technology spending and operational improvements, such as lower growth in the operating expenses (8, 43) and improved cost efficiency and profitability (6, 41).

MEASURING PERFORMANCE

Researchers have examined the potential performance benefits from information systems at the level of the economy, industry, business, and individual (13, 15, 16, 17). Although inconclusive, this body of research suggests that the use of IS can in some circumstances provide significant individual and organizational benefits. Dehning and Richardson (2002) synthesize and develop a model to guide future research in the evaluation of IT investment (15). The question of interest to us is whether there are indeed benefits from using one specific type of IS: the KMS is an IS explicitly designed to change the way in which the managers enhance and support their decision making. Hence, we summarize some research between performance measurement and information technology in Table 1 and select proper ratios as financial performance indicators for this study.

The profit performance of the KMS adopters and non-adopters is compared using four profit-based measures focusing on net income and operating income. The ratios are scaled by measures of firm size based on sales and total assets. The first two ratios, return on assets (ROA) and return on sales (ROS) have been widely used in the IT business value literature as measures of business profitability (8, 12, 16, 28, 41, 42, 43, 45, 48). ROA has been shown related to several other measures of financial performance and as the best overall measure of financial performance. Since ROA incorporates both business profitability and efficiency (45), it tends to be a useful overall performance indicator (28). The ROS, which is the ratio of net income to sales, serves as another indicator of a firm's net profit margin (8, 15). Asset turnover (ATO) measures the sales generated per dollar of assets, which is a measure of asset efficiency (16, 28). The operating income to assets (OI/A)

focuses on operating returns only and excludes incomes earned by the business from other sources such as interest income and income from other extraordinary sources. The operating income is regarded as a more appropriate measure of the direct value of IT (8).

TABLE 1
Summary Research on the Performance Measurement in IT

Author	Focus of Study	Measure	Summary of Major Findings
Bharadwaj (8)	Relation between IT Capability and Firm Performance	ROA, ROS, OI/ASSETS, OI/S, OI/EMP, COGS/S, SG&A/S, OEXP/S	High IT Capable firms have higher profitability ratios in all four years, lower OEXP/S in all four years, and COGS/S lower in two out of four years.
Dehning and Stratopoulos (16)	Relation between IT-enabled Strategies, and Profitability and Efficiency	ROA, ROS, ATO	CWP100 companies have higher ROA for all seven years. ROS is higher four out of the seven years, and ATO is higher all seven years.
Hitt and Brynjolffson (26)	Relation between IT Stock and Profitability Ratios	ROA, ROE	A positive relation between IT stock and ROA, no relation between IT Stock and ROE. IT benefits productivity and causes an increase in consumer surplus.
Hunton et al. (29)	Comparing firm performance of adopting ERP and non-adopter	ROA, ROS, ATO, ROI	Results indicate that ROA, ROI and ATO were significantly better over a 3-year period for adopters than non-adopters.
Mitra and Chaya (37)	Relation between IT Spending, and Productivity and Efficiency	OEXP/S, GM%, SG&A/S, LABOR/S	Higher IT spenders have lower OEXP/S, COGS/S, and higher SG&A/s. Large firms spend a larger percentage of their revenue on IT than smaller firms do.
Poston and Grabski (41)	Affect of ERP Implementation on Firm Performance	SG&A/Revenues, COGS/Revenues, EMP/S, Residual Income	On an inter-firm basis they find increases in SG&A/Revenues and COGS/Revenues the year after implementation, a decrease in COGS/R three years after implementation, and a decrease in EMP/S all three years after implementation.
Rai et al. (42)	Relation between Multiple IT Spending Measures and Performance and Efficiency Measures	Value, Sales, ROA, ROE, Labor Productivity, Administrative Productivity	Positive relation between firm output and all spending measures, a positive relation between IT capital and ROA. Labor productivity relates positively to IT capital. Administrative productivity relates negatively to software expenditures and telecom expenditures.
Santhanam and Hartono (43)	Relation between IT Capability and Firm Performance	ROA, ROS, OI/ASSETS, OI/S, OI/EMP, COGS/S, SG&A/S, OEXP/S	Firms with superior IT capability indeed exhibit superior current and sustained firm performance when compared to average industry performance, even after adjusting for effects of prior firm performance.
Tam (48)	Relation between IT Stock and Profitability Ratios in Four Asian Countries	ROA, ROE, ROS	Positive relation between computer capital (CC) and ROA in Singapore, a negative relation between CC and ROA in Taiwan, a negative relation between CC and ROE in Taiwan, and a negative relation between CC and ROS in Hong Kong.

ADMINISTRATIVE PRODUCTIVITY = VALUE divided by Selling, General, and Administrative Expenses; COGS/S = Cost of Goods Sold as a percent of Sales; EMP/S = Number of Employees divided by Sales; GM% = Gross Margin Percentage; LABOR/S = Total Labor Cost as a percent of Sales; LABOR PRODUCTIVITY = VALUE divided by Total Employees; OEXP/S = Operating Expenses as a percent of Sales; OI/ASSETS = Operating Income divided by Assets; OI /S = Operating Income divided by Sales; OI /EMP = Operating Income divided by Number of Employees; ROA = Return on Assets; ROE = Return on Equity; ROS = Return on Sales; SG&A/S = Selling, General, and Administrative Expenses as a percent of Sales; ATO = Total Assets Turnover; and VALUE = Sales minus Labor Expenses.

KMS is not a production automation tool and is not expected to impact overall production costs. Selling, general, and administrative (SG&A) expenses are period costs, which are not directly related to the acquisition or production of goods. Selling expenses result from the company's efforts to make sales, while general and administrative expenses result from the general administration of company's operations. Cost of goods sold (COGS) reflects the direct costs and overhead associated with the physical production of products for sale. Typical product overhead costs include: power, heat, light, property taxes on factory, factory supervisory labor, depreciation of plant assets, and supplies (31, 41). Amir and Lev (1996) point out that firm's expensing intangible assets are appearing in aggregate SG&A expenses in the profit and loss statement (2). This study uses four ratios to measure firm performance: total operating expenses to sales (OEXP/S), COGS to sales (COGS/S), SG&A

to sales (SG&A/S), and the employees to sales (EMP/S). The total operating expenses (defined as the sum of COGS and SG&A) serve as a proxy for the business' total cost of operations (8). The operating expense is selected because it is the most general and encompassing measure of a firm's total cost of operations (37). The COGS and SG&A expenses are the generally accepted accounting measures for the production and overhead costs of a firm (8). The number of employees to sales (EMP/S) is used as a measure of the productivity per employee (26, 41).

Based on the above discussion, we use eight ratios to measure business performance. Descriptions of the performance variables, along with interpretation of these ratios are shown on Table 2. We use these ratios in our study to determine firm performance. The eight ratios can be classified into two categories: one is profit ratio, while the other is cost ratio.

TABLE 2
Financial Performance Variables

Ratio	Calculation	Interpretation
ROA	Income available to common shareholders from continuing operations divided by average total assets.	Measures profitability and efficiency of assets employed; the **higher** ratio indicates more profitability.
ROS	Income before extraordinary items divided by net sales for the period.	Measures the firm's profit margin; the **higher** ratio indicates more profitability.
ATO	Asset turnover is net sales for the period, divided by the average of the beginning and ending total assets.	Measures how efficiently management utilized assets to generate sales; the **higher** ratio indicates more profitability.
OI/A	Operating income is earnings before taxes and depreciation divided by average total assets	Measures the direct value of IT; the **higher** ratio indicates more profitability.
EMP/S	Total number of employees divided by net sales for the period.	Measures the productivity per employee; the **lower** ratio indicates more productivity.
SG&A/S	SG&A expenses expense divided by sales. SG&A expenses are not directly related to the acquisition or production of goods.	Measures the costs that are not directly related to the acquisition or production of goods; the **lower** ratio indicates more profitability.
COGS/S	COGS divided by sales. COGS reflects the direct costs and overhead associated with the physical production of products for sale.	Measures the direct cost allocated by the company to production and overhead; the **lower** ratio indicates more profitability.
OEXP/S	Operating expenses is the sum of COGS and SG&A divided by sales.	Measures a firm's total cost of operations; the **lower** ratio indicates more profitability.

Profit Ratios: Return on assets (ROA) (8, 12, 16, 29, 41, 42, 43, 45, 48), return on sales (ROS) (8, 16, 29, 41, 42, 43, 48), Asset Turnover (ATO) (16, 29), and operating income to assets (OI/A) (8, 43).

Cost Ratios: Cost of goods sold to sales (COGS/S) (8, 41, 43), selling and general administration expenses to sales (SG&A/S) (8, 37, 41, 43), operating expenses to sales (OEXP/S) (8, 37, 43), and number of employees to sales (EMP/S) (26, 41).

RESEARCH HYPOTHESES

The fundamental premise is that a KMS that can improve firm performance may produce long-term sustainable competitive advantage for the organization (1, 46, 49). They believe that the value derived from using the IS will exceed its cost. There have been many studies and much debate over the value derived from using the IS. The so-called "productivity paradox" has been a long-running research theme (11, 12, 13). Because the assessment of the economic impact of IT is of critical importance to IS researchers, more research using unifying theory-based frameworks is necessary (13). In the RBV research, firms can devise strategies to create and sustain advantages from investments in IT (19). Researchers have shown that a firm's ability to effectively leverage its IT investments by developing a strong IT capability can result in improved superior performance of the firm (43). On the other hand, the transaction cost perspective economics proposes that a firm is an economic entity created in an effort to economize on market transaction costs (24). As such, the KMS adopters might reduce costs and increase revenues by adopting KMS to accumulate knowledge assets and by providing better document management to improve decision-making and customer relationship management. Giving managers desirable access to the knowledge repository, they can efficiently review and effectively retrieve the knowledge in a timely manner.

The benefits of superior KM capability must be sustainable over time. But the sustained competitive advantage does not imply that the benefits will last forever (4). Prior research has also indicated that a time lag is necessary for capturing the performance improvements from information technology (11, 12, 34). Therefore, this study follows the suggestions of prior research and does not count financial data of the firm in the immediately following fiscal year when KMS adopters were announced. Though the sample size is further reduced, this practice will allow us to examine the firm performance more objectively. In summary, while the accumulated knowledge assets of KMS adopters are complex to acquire and difficult to imitate, firms that achieve competitive advantage through KMS have also learned to effectively combine their other resources to create an overall KM capability. Firms those are successful in creating superior KM capability with superior financial performance by increasing revenues and decreasing costs.

Therefore, we propose our research hypotheses. The first two hypotheses H1 and H2 investigate the firms that adopt KMS should have better performance in subsequent years than prior to the adoption of KMS. The second two hypotheses H3 and H4 investigate performance differences between KMS adopters and non-adopters, whether KMS adopters have superior performance than the others in the same industry and with similar firm size. Due to the nature of KMS and its predicted association with

decreased administrative costs, information search costs, operational costs, improved decision-making, competitive advantage, and increasing revenues, the research hypotheses can be tested based on the eight ratios of SG&A/S, COGS/S, OEXP/S, ROA, ROS, OI/A, ATO, and EMP/S as stated below:

Hypothesis1: The **cost ratios** of KMS adopters should be reduced after adopting KMS in subsequent years.

H1.1: $SG\&A/Sales_{POST} < SG\&A/Sales_{PRE}$

H1.2: $COGS/Sales_{POST} < COGS/Sales_{PRE}$

H1.3: $Operating\ Expenses\ /Sales_{POST} < Operating\ Expenses\ /Sales_{PRE}$

H1.4: $Number\ of\ Employees/Sales_{POST} < Number\ of\ Employees/Sales_{PRE}$

Hypothesis2: The **profit ratios** of KMS adopters should be increased after adopting KMS in subsequent years.

H2.1: $ROA_{POST} > ROA_{PRE}$

H2.2: $ROS_{POST} > ROS_{PRE}$

H2.3: $Operating\ Income/Assets_{POST} > Operating\ Income/Assets_{PRE}$

H2.4: $Asset\ Turnover_{POST} > Asset\ Turnover_{PRE}$

Eliashberg and Chatterjee (1985) demonstrate that prices drop immediately after the adoption of innovative technologies and demand increases as a result of price sensitivity. They further indicated that the financial performance of adopters might or might not improve significantly, depending on a host of exogenous factors such as competitive intensity, industry heterogeneity, demand uncertainty, and adoption rate of competitor firms (20). Nevertheless, the performance of non-adopters would be expected to deteriorate by comparison in a competitive marketplace. Hunton et al. (2003) examine the longitudinal impact of ERP adoption on firm performance with peer firms that had not adopted ERP systems. Their results indicate that ROA, ROI, and ATO are significantly better over a 3-year period for adopters, as compared to non-adopters (28). If we view KMS adoption through this lens, we would anticipate the financial performance of non-adopters to decline relative to adopters. Hence, we propose the following hypothesis:

Hypothesis 3: The **cost ratios** of KMS adopters will be lower than the non-adopters in the same firm size and industry.

H3.1: $SG\&A/Sales_{Adopter} < SG\&A/Sales_{Non\text{-}Adopter}$

H3.2: $COGS/Sales_{Adopter} < COGS/Sales_{Non\text{-}Adopter}$

H3.3: $Operating\ Expenses\ /Sales_{Adopter} < Operating\ Expenses\ /Sales_{Non\text{-}Adopter}$

H3.4: $Number\ of\ Employees/Sales_{Adopter} < Number\ of\ Employees/Sales_{Non\text{-}Adopter}$

Hypothesis 4: The **profit ratios** of KMS adopters will be higher than the non-adopters in the same firm size and industry.

H4.1: $ROA_{Adopter} > ROA_{Non\text{-}Adopter}$

H4.2: $ROS_{Adopter} > ROS_{Non\text{-}Adopter}$

H4.3: $Operating\ Income/Assets_{Adopter} > Operating\ Income/Assets_{Non\text{-}Adopter}$

H4.4: $Asset\ Turnover_{Adopter} > Asset\ Turnover_{Non\text{-}Adopter}$

THE RESEARCH METHOD AND DATA COLLECTION

This study tests the proposed hypotheses using archival financial data extracted from COMPUSTAT, which includes the financial statements of almost all US-based publicly traded corporations. To identify firms that adopted KMS, we carefully select the qualified KMS vendors from the KM World Magazine. It publishes the KM World's 100 companies, which provide different kind of KM applications in its March 2003 issue. This study collects KMS adopters as our research cases. We search the Reuters.com (http://cnbc.investor.reuters.com) for the key developments of KMS vendors that have publicly disclosed firms who acquired their KM applications. Since Reuters.com provides the public announcement data after 1999, as the result of this constraint, the samples of KMS adopters are from 1999 to 2003. The distribution of KMS adoption firms by announcement year is presented in Appendix B. KMS Vendors and the one-digit SIC codes associated with each vendor are reported in Appendix D. Firms have to satisfy the following criteria to be included in our samples. First, they have to be listed on the COMPUSTAT. Additionally, they have to be active as of the end of 2003 fiscal year.

In our tests of the effect of KMS adopters on firm performance, we also control for macroeconomic conditions that could influence test results. The following steps are applied to create a matching set of control firms drawn from the COMPUSTAT. Similar methodologies have been employed in previous studies of firm performance (3, 8, 28). First, the KMS adopters are grouped into different industry categories based on their SIC code. A two-step process is then used to identify a matching firm for each firm in the sample of KMS adopters. For each firm in KMS adopters sample, the choice is narrowed to a set of only those firms with the same primary four-digit SIC code as the KMS adopters. Next, from the set of potential control firms, the matching control firm chosen has similar total asset and sales level of the KMS adopters. If the number of control firms listed at COMPUSTAT has more than one, the random number table is applied to determine the control firms. The firms in each pair are drawn from the same industry and are of equal size. Matching on size and industry helps to rule out exogenous factors as alternative explanations for any difference found in performance between the two groups. To accomplish this objective, we compared the financial performance of 74 KMS adopters to 74 non-adopters in a matched-pair design (see appendix C).

To ensure that no KMS adopters are included in the control sample, we conducted secondary data survey to determine whether the identified firms have indeed adopted the KMS. Similar methodologies have been employed in previous studies to examine the firm performance (25, 27). With respect to the non-adopters, we use the keywords such as knowledge management, document management, business intelligence, and customer relationship management through Lexis-Nexis and Reuters.com and find that none of the control firms had a news wire disclosure concerning KMS adoption.

In the first two hypotheses, H1 and H2 examine the changes in firm performance from one year before to one and two years after adopting KMS, which depends on the public announcement date of KMS adopters. However, for the second two hypotheses H3 and H4, we test for differences between pre- and post-adoption for KMS adopters and non-adopters. Additionally, we conduct a regression analysis of performance differences between KMS adopters and non-adopters. The regression model allows us to control for the firms' pre-adoption

performance. In this regression model, we regress performance measures on pre-adoption financial data with a dummy variable, which represents KMS adopters versus non-adopters as follows:

$$\text{Financial Ratio} = \alpha + \beta_1 \text{ Pre-Ratio} + \beta_2 \text{ Non-KMS Adopter} + \varepsilon$$

where Financial Ratio denotes post-adoption performance as measured by performance in the time period t_{+2} and t_{+1} for all ratios. Pre-Ratio denotes pre-adoption performance as measured in the time period t_{-1} for all ratios. Non-KMS Adoption = 0 if the firm is a non-adopters, and 1 if the KMS is an adopter; and ε is the error term. Since the model involves an additional dummy variable, the significance of the coefficient (β_2) of this variable indicates whether adopting the KMS has a statistically significant effect on performance. Barber and Lyon (1996) indicate that in addition to controlling for industry and size, it is important that the previous performance should be controlled in models testing for abnormal performance (3). The Pre-Ratio variable (t_{-1}) represents such a lagged performance measure.

RESULTS

Descriptive Statistics

The two groups of KMS adopters and non-adopters are also compared using commonly employed measures of firm size such as sales and total assets. A t-test is carried out to check if there are any differences between the two groups. Table 3 provides descriptive statistics for the two groups. The mean sales figure for the KMS adopters and non-adopters are \$48.44b (\$19.32b) and \$46.13b (\$15.47b) billions of dollars respectively in 1999 and 2000. Meanwhile, the mean total asset figures for the KMS adopters and non-adopters are \$42.69b (\$17.08b) and \$39.31b (\$13.54b) billions of dollars. The two samples appear to be well matched on size, since the means tests do not reveal any significant differences between the two groups. A complete list of the KMS adopters and non-adopters that are included in each group is shown in Appendix C.

TABLE 3
Descriptive Statistics for KMS Adopters and Non-adopters

Item	Sample	N	Mean	Standard deviation	t statistic	P-value
Time (1999)						
Total Asset	KMS adopters	74	42.69	88.96	0.507	0.614
	Non-adopters	74	39.31	94.90		
Sales	KMS adopters	74	48.44	116.92	0.324	0.747
	Non-adopters	74	46.13	119.15		
Time (2000)						
Total Asset	KMS adopters	74	17.08	33.06	1.240	0.219
	Non-adopters	74	13.54	30.05		
Sales	KMS adopters	74	19.32	38.14	1.295	0.200
	Non-adopters	74	15.47	34.85		

t value significant at .05 level (**), dollar amounts in billion \$.

Hypotheses 1 and 2

The results of the tests of hypotheses are reported in Table 4. In this study, firms' performance is divided into two time periods—pre-adoption and post-adoption. The fiscal year of the KMS announcement, identified as year zero (t_0), serves as the baseline year for aligning the KMS-adopting firms. Similar methods have been done in prior studies to examine the firm performance (10, 28). Prior research suggests that a time lag should be factored in to estimate IT effects due to learning curve (8, 12, 43). Hence, we perform statistical tests only on those firms that have announced their adoption of KMS with at least two years. The pre-adoption period denotes the first years (t_{-1}) before the adoption of KMS. The post-adoption period denotes each year (t_{+2}, t_{+1}) after adopting KMS for all ratios. Small sample size may disrupt and confound findings. Paired samples t-tests can be controlled for firm and industry effects by minimizing the variance within the individual firm (41). Therefore, we apply the paired samples t-tests to compare firm performance ratios before versus after KMS adoption. The results of the tests are listed in Table 4.

In the cost ratios, results indicate that KMS adopters are found to be associated with a significant decrease (t = -1.701, P =.094) in the operating expenses divided by sales (OEXP/S) after the second year. The results indicate that KMS adopters are also found to be associated with a significant decrease (t = -1.911, P =.061) in the selling, general, and administrative costs divided by sales (SG&A/S) after the second year. Thus, hypotheses 1.1 and 1.3 are supported. However, KMS adopters are not found to be associated with a significant decrease in the cost of goods sold divided by sales (COGS/S) after the first and second year. Therefore, hypothesis 1.2 is not supported. The KMS adopters are associated with a significant decrease (t = -1.949, P =.055) in the number of employees divided by sales (EMP/S) after the second year. As mentioned earlier, this ratio is lower than before adopting KMS, which represents more productivity. Hence, the result indicates that hypothesis 1.4 is partially supported and illustrates an improvement in the productivity of KMS adopters.

Although contrary to the hypothesis, the result for COGS/S ratio is in line with the results reported in recent studies that

examined the association between IT investment and cost ratios (8, 37, 41). These studies found that higher IT investment typically incurred higher overhead costs per unit of output and, therefore, had higher than average COGS expenses. The operating expenses are defined as the sum of COGS and SG&A representing a proxy for the firm's total cost of operations. Our results empirically confirm the claims with insignificant COGS/Ss and further confirm that KMS does improve firm performance in decreasing SG&A expenses. SG&A expenses are not directly related to the acquisition or production of goods costs, but the COGS reflects the direct costs and overhead associated with the physical production of products for sale. The main purpose of KMS is to reduce the administrative expenses. Therefore, adopting KMS lessens the SG&A expenses from our results.

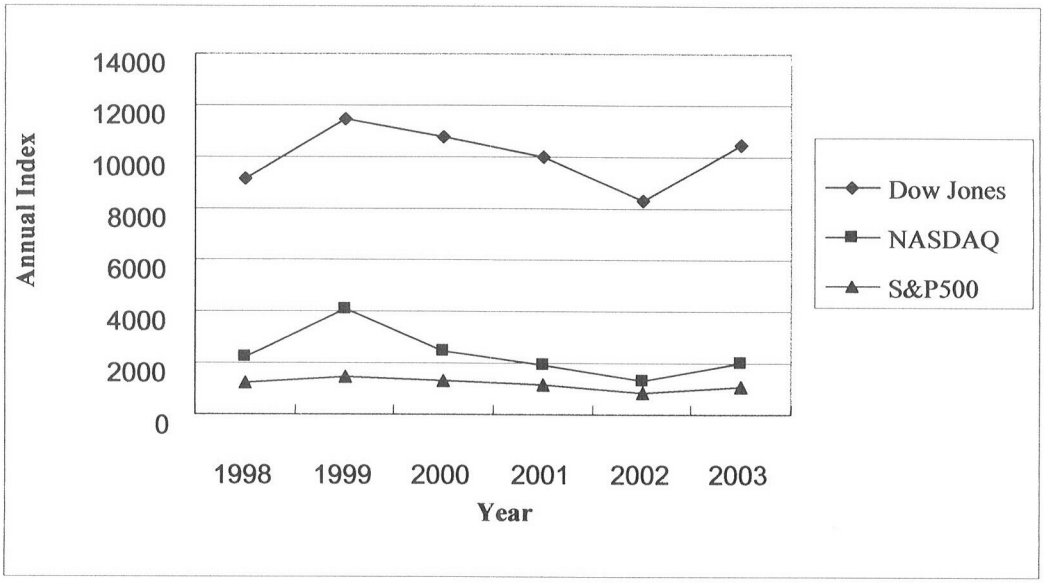
However, the profit ratios are contrary to our expectations, the results are either insignificant or significant with reverse signs. It should be noted that in Table 4, the P values of the three ratios ROA and asset turnover (ATO) in the two consecutive years and the operating income (OI/A) in the first year after adopting KMS, are significant but t-statistics are not in the expected direction. The macroeconomic environment may have influence on the firms' performance so that KMS effects could not be detected adequately. Given the downturn of economy for the past three years, most firms suffered their performance and declared those three years as their worst ones. Appendix A lists the annual indexes of Dow Jones, NASDAQ and S&P500. The three major industry indexes deteriorated clearly from 1999 to 2002 as depicted in Figure 1. The data of this study are collected among those three years. The invisible hand has strong impact on the firm performance which may have dwarfed our findings. As a result, this study tries to control the macroeconomic effects in the following section.

TABLE 4
Pairwise Sample T test Results for Difference in All Ratios for Adopting KMS Firms
(t statistic (P value)); ($(t+2,t+1)$ vs. t_{-1}), n=74

Comparison of Ratio After vs. Before KMS Adoption								
Ratios	**SG&A/S**	**COG/S**	**OEXP/S**	**EMP/S**	**ROA**	**ROS**	**OI/A**	**ATO**
1st year after vs. year before	-0.563 (.575)	1.560 (.123)	0.163 (0.871)	-1.369 (.176)	-1.900 **(.061) ***	-1.525 (.132)	-3.473 **(.001) ****	-2.813 **(.006) ****
2nd year after vs. year before	-1.911 **(.061)***	1.112 (.270)	-1.701 **(.094)***	-1.949 **(.055)***	-2.404 **(.019) ****	0.441 (.660)	-1.408 (.164)	-2.153 **(.035) ****

t value significant at .05 level (**), one-tail and .10 level (*); 'bold' indicate instances where after the firms adopting KMS performed better.

FIGURE 1
The Annual Indexes of Dow Jones, NASDAQ and S&P 500



Hypotheses 3 and 4

Table 5 shows the results of the regression analyses that seek to examine the effects of KM capability between KMS adopters and non-adopters. It is important to note that in analyzing the effects of KM capability, a significant positive coefficient for the dummy variable related to profit ratios and a significant negative coefficient for the dummy variable related to cost ratios indicate the effects of KM capability on the differences of performance after adopting KMS. As seen in Tables 5, the variation in the magnitude and levels of significance depends on the year of adoption. Hence, to analyze the time effect, the study divides the table into two time periods: t_{+2} and t_{+1}. Further, in the cost ratios, results indicate that SG&A/S (t = -1.987, P =.050) and OEXP/S (t = -1.817, P =.072) are significantly different between KMS adopter and non-adopters in the first year but insignificant in the second year. Hypotheses 3.1 and 3.3 are supported. These results are in line with the results reported in Table 4 that shows the differences of KMS adopters between pre- and post-adoption. Additionally, there is no significant difference in EMP/S between the KMS adopters and non-adopters, although EMP/S does decline between the pre- and post-adoption periods for non-adopters comparing to KMS adopters. Thus, hypotheses 3.2 and 3.4 are not supported.

TABLE 5
Regression Results for All Ratios, Controlling for Pre-adopting Results, n=148

Financial Ratio = $\alpha + \beta_1$ Pre-Ratio + β_2 Non-KMS Adopter + ε			
Financial Ratio = t_{+1}			
Financial Ratio	**Pre-Ratio**	**Non-KMS Adopter**	**R-Square**
SG&A/S	1.169 (32.240) (<.001) **	**-0.103 (-1.987) (.050) ***	0.898
COGS/S	0.625 (12.229) (<.001) **	0.002 (0.053) (.957)	0.508
OEXP/S	1.163 (28.292) (<.001) **	**-0.109 (-1.817) (.072) ***	0.872
EMP/S	0.569 (8.078) (<.001) **	-0.090 (-0.125) (.901)	0.323
ROA	1.110 (5.381) (<.001) **	10.880 (1.105) (.271)	0.183
ROS	1.919 (7.771) (<.001) **	0.207 (2.354) (.107)	0.301
OI/A	0.926 (9.711) (<.001) **	0.021 (0.494) (.622)	0.406
ATO	0.729 (15.456) (<.001) **	**0.098 (1.830) (.069) ***	0.716
Financial Ratio	**Pre-Ratio**	**Non-KMS Adopter**	**R-Square**
SG&A/S	0.384 (16.464) (<.001) **	-0.029 (-0.850) (.397)	0.689
COGS/S	0.561 (10.522) (<.001) **	0.036 (1.159) (.248)	0.439
OEXP/S	0.315 (16.759) (<.001) **	-0.017 (-0.615) (.540)	0.707
EMP/S	0.520 (7.053) (<.001) **	-0.076 (-1.028) (.306)	0.272
ROA	0.632 (5.942) (<.001) **	**10.964 (2.213) (.029) ** **	0.237
ROS	0.245 (5.084) (<.001) **	**0.207 (2.354) (.020) ** **	0.187
OI/A	0.443 (6.768) (<.001) **	0.044 (1.560) (.121)	0.269
ATO	0.747 (11.328) (<.001) **	**0.103 (1.822) (.071) ***	0.669

Coefficient, (t statistic) (P value), t value significant at .05 level (**), one-tail and .10 level (*); 'bold' indicate instances where the KMS adopters performed better.

In the profit ratios, Table 5 shows that performance of KMS adopters differs apparently from non-adopters until second years after adoption on ROA (t = 2.213, P =.029) and ROS (t = 2.354, P =.020). Hypotheses 4.1 and 4.2 are supported. Additionally, there is significant difference in ATO (P<.10) between KMS adopter and non-adopters in all two years. Thus, hypothesis 4.4 is supported. Although operating income divided by asset (OI/A) of KMS adopters appeared to be better than non-adopters, the difference was not significant. Hypothesis 4.3 is not supported. The results reported on Table 5 indicate that performance benefits accruing from KMS adoption may take time to materialize. Mahmood et al. (1998) point out that there is a 2-year lag between the investment in IT and an improvement in financial performance (34). Our results also empirically confirm their claims by examining the differences between KMS adopters and non-adopters. Overall, test results partially support hypotheses 3 and 4.

CONCLUSION

According to the statistical results of this study, the COGS to sales (COGS/S) is insignificant. As previous research has shown an inconsequential relationship between IS and the reduction of production costs (8, 37, 41), this research confirms the insignificance of COGS/S. However, there are substantial decreases in SG&A to sales (SG&A/S), the operating expenses to sales (OEXP/S), and the number of employees to sales (EMP/S) in the second year after adopting KMS. The main purposes of KMS are to reduce administrative expenses and to improve productivity by maximizing KM capability. Giving managers necessary access to the knowledge repository, they can efficiently review and effectively retrieve the timely information, thereby providing essential knowledge for better decision makings. This study supports the claim that adopting KMS does help lessen the SG&A expenses and strengthen productivity.

The effects of reduced SG&A costs are not obvious in the first year after adopting KMS due to the learning curve, but the effects become significant in the second year after adopting KMS. It may contribute to the maturity of IT, and in this case, the maturity of KMS. The employees need time to adjust themselves to their own utilization. The time lag allows them to

find ways for the new system to support their work. It seems that end users of the adopted KMS overcome the learning curve and become productive. They seem to use more effective KMS applications to reduce work risk. Hence, the cost ratios related to SG&A are significantly reduced in the second year. The findings are aligned with former IS research.

Given the profit ratios contrary to our expectations, the macroeconomic environment may influence the firm's performance. Therefore, KMS effects could not be detected adequately. This study thus attempts to control the macroeconomic effects and to create a matching set of non-adopters. In the cost ratios, the results indicate the significant difference of SG&A/S and OEXP/S in the first year between KMS adopter and non-adopters. In the profit ratios, the results display the difference of performance of KMS adopters and non-adopters until the second year after adopting KMS on ROA and ROS. Additionally, significant differences in ATO between KMS adopter and non-adopters exist in the two entire years. These results reveal that KMS adopters have superior KM capability than non-adopters in light of ROA, ROS, and ATO that determine the productivity and profitability of firms. The findings thus provide new insights into the productivity paradox associated with KMS adopters and confirm that KMS adopters help firms gain a competitive advantage over non-adopters.

This paper is one of the first papers to consider the contribution of KMS to firm performance across industry sectors. Although a considerable research has been developed to understand the mechanisms of KM and the difficulties in KMS implementation (23, 28, 32, 38, 47), few studies have been able to quantify the benefits in a manner that is consistent across firms. This research attempts to analyze the impacts of KMS on the firm performance using financial data extracted from the COMPUSTAT. The findings of this study provide significant implications for IS researchers and practitioners that KMS support and enhance a wide array of business processes and decrease the administrator cost for professional managers. From a practitioner perspective, this study makes it clear that, despite the potentially high adopting costs, the average KMS implementation is a productive investment.

There are some limitations on this study. First, we use the Reuters.com to search KM vendors who have publicly disclosed client companies that have selected their KM solutions after 1999. Though the search turns out 255 subject companies adopting KMS from 1999 to 2003, we will not be able to analyze those firms that adopted KMS before 1999. The major portals such as Cnnfn.com, Yahoo.com and MSN.com have the same cutoff date on 1999. Second, COMPUSTAT publishes the financial data of public companies. Private companies that adopted KMS are excluded from this study. Third, to compensate the time lag of IT adoption, we only selected the firms that adopted KMS in 1999 and 2000, which have at least 2-year data for our data analysis. This time frame may be insufficient to capture the long-term effects of KMS on firm performance. Future research should be continued when new fiscal year data becomes available in order to see the longitudinal effects of KMS on firm performance. Furthermore, researchers may re-test RBV theory through survey research or case data and examine competing reasons that might explain why the relative performance of non-adopters declines compared to KMS adopters. Finally, it would be useful to examine in more detail how firm-specific factors, such as intangible assets or human capital, affect both the cost of research and development as well as the benefits received.

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APPENDIX A
The Annual Indexes of Down Jones, NASDAQ and S&P500

Year	Dow Jones	NASDAQ	S&P500
1998	9183.43	2192.69	1229.23
1999	11497.12	4069.31	1469.25
2000	10787.99	2470.52	1320.28
2001	10021.57	1950.4	1148.08
2002	8341.63	1335.51	879.82
2003	10453.92	2003.37	1111.92

APPENDIX B
The Distribution of KMS Adoption Firms

Announcement Date	Number of KMS Cases	Percentage
2003 IV	3	
2003 III	5	
2003 II	12	
2003 I	10	11.8%
2002 IV	17	
2002 III	16	
2002 II	15	
2002 I	21	27.0%
2001 IV	20	
2001 III	21	
2001 II	20	
2001 I	15	29.8%
2000 IV	15	
2000 III	21	
2000 II	11	
2000I	10	22.4%
1999 IV	11	
1999 III	8	
1999 II	4	9.0%
Total	**255**	**100%**

APPENDIX C
List of KMS Adopters and Non-adopters

No	KMS Adopters	SIC	Announced Date	Non-adopters
1.	OAKWOOD CO.	2451	December 20, 2000	CHAMPION ENTERPRISES INC
2.	CONCORD EFS, INC.	6099	December 18, 2000	VIAD CORP
3.	BARNES & NOBLE INC	5940	December 07, 2000	OFFICEMAX INC
4.	SEGUE SOFTWARE	7372	November 27, 2000	FIREPOND INC
5.	AFLAC INC	6321	November 09, 2000	UNUMPROVIDENT CORP
6.	SCHWAB CHARLES CO	6211	October 30, 2000	E TRADE FINANCIAL CORP
7.	COMPUCOM SYSTEM	5045	October 23, 2000	INTRAWARE INC
8.	DELTA AIR LINES	4512	October 19, 2000	UNITED AIRLINES INC
9.	TEXAS INSTRUMENTS	3674	October 09, 2000	INFINEON TECHNLGIES
10.	FREEMARKET INC	7389	October 06, 2000	RAE SYSTEMS INC
11.	AMERICAN AIRLINES	4512	October 05, 2000	UAL CORP
12.	MOTOROLA INC	9997	October 04, 2000	ERICSSON (L M) TEL -ADR
13.	SIEMENS AG-ADR	3663	October 04, 2000	TEXTRON INC
14.	SIEBEL SYSTEMS INS	7372	October 02, 2000	VERITAS SOFTWARE
15.	APPLERA CORP APPLIED BIOSYS	3826	September 28, 2000	APPLERA CORP- ONSOLIDATED
16.	CREDIT SUISSE FIRST BOS USA	6211	September 28, 2000	LEHMAN BROTHERS HOLDINGS INC

17.	XILINX INC	3674	September 26, 2000	BROADCOM CORP -CL A
18.	BP PLC-ADS	2911	September 19, 2000	EXXON MOBIL CORP
19.	BARCLAYS PLC-ADR	6020	September 11, 2000	J P MORGAN CHASE & CO
20.	NOVELL INC.	7372	September 08, 2000	VERISIGN INC
21.	COMPUTER SCIENCES	7370	September 05, 2000	CMGI INC
22.	ROYAL & SUN ALLIANCE-ADR	6331	August 31, 2000	SWISS REINSURANCE CO
23.	ROCKWELL AUTOMATION	7370	August 29, 2000	AMERICAN PWR CNVRSION
24.	HARRIS INTERACTIVE	3711	August 16, 2000	EARTHLINK INC
25.	FORD MOTOR CO	3533	August 15, 2000	GENERAL MOTORS CORP
26.	BORDERS GROUP	5940	August 14, 2000	BARNESANDNOBLE.COM INC
27.	GENERAL ELECTRIC	9997	August 14, 2000	TYCO INTERNATIONAL LTD
28.	GLOBAL SOURCES LTD	2834	August 14, 2000	INTERNET CAP GROUP INC
29.	NATIONAL-OILWELL	3861	August 14, 2000	GRANT PRIDECO INC
30.	ASTRAZENECA - ADR	3721	August 11, 2000	AVENTIS SA -ADR
31.	AVAYA INC	7372	August 10, 2000	LORAL SPACE & COMMUNICATIONS
32.	EASTMAN KODAK	6311	July 31, 2000	PANAVISION INC
33.	BOEING CO	3576	July 17, 2000	BUTLER NATIONAL CORP
34.	ART TECHNOLOGY GROUP	6311	July 14, 2000	ARIBA INC
35.	DEERE & CO	2320	July 05, 2000	KUBOTA CORP -ADR
36.	GOLDMAN SACHS GROUP INC	3089	June 07, 2000	MERRILL LYNCH & CO
37.	LUCENT TECHNOLOGIES INC	3760	May 17, 2000	EQUANT N V -ADR
38.	AMERICAN INTERNATIONAL GROUP	7370	May 15, 2000	AXA -SPON ADR
39.	JUNIPER NETWORKS INC	3630	May 03, 2000	ENTERASYS NETWORKS INC
40.	PRINCIPAL FINANCIAL GRP INC	7370	April 25, 2000	HANCOCK JOHN FINL SVCS INC
41.	QUIKSILVER INC	4911	April 17, 2000	SPORT-HALEY INC
42.	MYERS INDUSTRIES	7370	April 10, 2000	ENTEGRIS INC
43.	LOCKHEED MARTIN	2834	April 05, 2000	SPACEHAB INC
44.	WHIRLPOOL CORP	7370	March 27, 2000	MAYTAG CORP
45.	LOUDEYE CORP	7372	March 08, 2000	WEBB INTERACTIVE SVCS INC
46.	NORTHEAST UTILITIE	7372	March 06, 2000	SUEZ -ADR
47.	MITEK SYSTEMS INC	3841	February 15, 2000	PRINTRONIX INC
48.	HEWLETT-PACKARD	3728	February 14, 2000	TOSHIBA CORP
49.	EBAY INC	7372	February 08, 2000	INTERLAND INC
50.	LILLY (ELI) & CO	6020	January 26, 2000	NOVARTIS AG -SPON ADR
51.	HEALTHSTREAM INC	3576	January 25, 2000	N2H2 INC
52.	WAL-MART STORES	7372	January 05, 2000	TARGET CORP
53.	ACCRUE SOFTWARE	3578	December 14, 1999	INTERGRAPH CORP
54.	BOSTON SCIENTIFIC	4813	December 14, 1999	BARD (C.R.) INC
55.	INTERSHOP COMMUN AG -ADR	7372	December 14, 1999	MERCURY INTERACTIVE CORP
56.	HONEYWELL INTERNATIONAL INC	2860	December 08, 1999	GOODRICH CORP
57.	INTELEFILM CORP	5311	December 08, 1999	DASSAULT SYSTEMES S A-ADR
58.	BANK ONE CORP	7371	December 01, 1999	WACHOVIA CORP
59.	CISCO SYSTEMS INC	3620	November 29, 1999	3COM CORP
60.	MICROSTRATEGY INC	2771	November 01, 1999	PROGRESS SOFTWARE CORP
61.	PAR TECHNOLOGY CO	3663	October 22, 1999	TRINTECH GROUP PLC -ADR
62.	NIPPON TELEGRPH & TELE -ADR	4812	October 21, 1999	DEUTSCHE TELEKOM AG
63.	CONCUR TECHNOLOGIES INC	5211	October 20, 1999	NATIONAL INSTRUMENTS CORP
64.	LYONDELL CHEMICAL CO	3575	September 14, 1999	INTL FLAVORS & FRAGRANCES
65.	SEARS ROEBUCK CO	3523	September 08, 1999	ITO YOKADO CO LTD
66.	WIND RIVER SYSTEMS INC	3578	August 30, 1999	KEANE INC
67.	AMERICAN GREETINGS	2711	August 16, 1999	HEALTHY PLANET PRODUCTS
68.	NEXTEL COMMUNICATIONS	6211	August 03, 1999	MMO2 PLC -ADR
69.	HOME DEPOT INC	7370	August 02, 1999	LOWES COS
70.	TELEVIDEO INC	3571	July 20, 1999	DOTRONIX INC
71.	NCR CORP	7372	June 30, 1999	HYPERCOM CORP
72.	TRIBUNE CO	3577	June 08, 1999	METRO INTL S A -CL B
73.	DELL INC	3570	April 18, 1999	NEC CORP -ADR
74.	AUTODESK INC	5331	April 12, 1999	BMC SOFTWARE INC

APPENDIX D
KMS Vendors and the One-digit SIC Codes Associated with Each Vendor

	One-digit SIC Codes									
KM Provider (Symbol)	10s	20s	30s	40s	50s	60s	70s	80s	90s	Total
Answerthink (ANSR)	-	1	-	4	-	-	1	-	-	6
Autonomy (AUTN)	-	1	-	-	1	-	2	-	-	4
BroadVision (BVSIN)	-	2	1	2	4	1	-	-	-	10
Business Object (BOBJ)	-	3	4	2	3	1	3	2	-	18
Captiva (CPTV)	1	-	3	-	-	2	1	-	-	7
Cognos (COGN)	-	3	2	1	1	3	-	-	-	10
CommerceOne (CMRC)	-	1	-	-	-	-	-	-	-	1
Computer Associates (CA)	1	1	5	3	-	1	1	-	-	13
Convera (CNVR)	-	-	1	-	1	1	6	-	-	9
DocuCorp (DOCC)	-	-	1	-	1	-	2	-	-	4
Documentum (DCTM)	-	2	9	1	1	-	3	-	-	16
DST Technology (DST)	-	-	1	-	1	-	-	-	-	2
Filenet (FILE)	-	2	2	-	1	1	1	-	-	7
Hummingbird (HUMC)	-	-	-	-	-	1	1	-	-	2
IBM	-	1	1	1	-	-	-	-	-	3
Informatica (INFA)	-	2	3	2	2	-	4	-	-	13
Interwoven (IWOV)	-	2	9	6	-	5	5	-	-	26
LION bioscience (LEON)	-	3	1	-	-	-	-	-	-	4
LionBridge(LIOX)	-	-	-	2	-	1	1	-	-	4
Mobius Management Systems (MOBC)	-	-	1	-	-	4	2	-	-	7
One Source (ONES)	-	-	-	-	-	2	2	-	-	4
OpenText (OTEX)	-	2	-	1	-	3	1	-	-	7
Oracle (ORCL)	-	1	3	3	-	2	1	-	1	12
Plumtree (PLUM)	-	2	1	-	-	-	-	-	-	3
Primus (PKSI)	-	-	2	1	1	-	5	-	-	9
Selectica (SLTC)	-	-	6	-	-	-	2	-	-	8
Service Ware (SVCW)	-	2	1	1	1	1	1	-	-	7
SPSS (SPSS)	-	-	1	-	1	1	1	-	-	7
Stellent (STEL)	-	1	3	-	1	2	-	-	-	7
Supportsoft(SPRT)	-	1	1	3	-	1	2	-	1	10
Sybase (SY)	-		1	-	-	2	1	1	-	5
Verity (VRTY)	-	1	-	-	-	2	1	1	-	5
Vignette (VIGN)	-	1	3	1	-	1	3	1	-	10
Total	**2**	**35**	**68**	**34**	**19**	**39**	**53**	**5**	2	**255**

One-digit sic codes represent the following industries: 10s = mining and construction, 20s = manufacturing (food, fabric, wood and paper, chemicals), 30s = manufacturing (metals, machinery and electrical), 40s = transportation and utilities, 50s = wholesale and retail businesses, 60s = financial services, 70s = business and entertainment services, 80s = professional services and 90s = others.