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# Financial impacts of enterprise resource planning implementations

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**Abstract**

Debate exists regarding the contribution of information technology to firm performance reflecting predictions of a positive, negative, or nonexistent relationship. Prior research has examined technology and firm performance in the aggregate, however, this study focuses on a specific technology — Enterprise Resource Planning (ERP) and its impact on firm performance. Economic and industrial organization theories provide the basis for the examination of how ERP systems affect firm coordination and transaction costs. ERP systems are expected to: (1) reduce costs by improving efficiencies through computerization; and (2) enhance decision-making by providing accurate and timely enterprise-wide information. These effects should be associated with improved firm performance. This research finds, after accounting for within-firm variances, no significant improvement associated with residual income or the ratio of selling, general, and administrative expenses in each of the 3 years following the implementation of the ERP system. However, a significant improvement in firm performance resulting from a decrease in the ration of cost of goods sold to revenues was found 3 years after the ERP system implementation (but not in the first or second year after implementation). Further, there was a significant reduction in the ratio of employees to revenues for each of the 3 years examined following the ERP implementation. 

*Keywords:* IT productivity; Economic theory; ERP

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## 1. Introduction

According to a 1999 survey of large multinational companies conducted by META Group, the average cost to implement and own an Enterprise Resource Planning (ERP) system is US$15 million per year and the time to deploy it has averaged 23 months (Knorr, 1999). Analysts reported that 70% of Fortune 1000 firms had or were in the process of installing ERP systems in 1998 (Hoffman, 1998), and that the ERP market experienced a compound annual growth rate of 35% in 1998 (Shepherd, 1998). Given this significant investment in ERP systems, the economic issue of whether ERP technology is associated with improved firm performance remains unanswered. This question is empirically addressed using archival financial data of Compustat firms that implemented ERP systems.

### *1.1. Description of ERP*

Most ERP software available on the market (i.e., from vendors like J.D. Edwards, Baan, Oracle, PeopleSoft, and SAP) is structured into different modules. Typical modules include accounting, human resources, manufacturing, and logistics. Each module is business process-specific, accesses a core/shared database, and can be considered a single application from both a user interface and software structure point of view. This structure enables users to develop module-specific competencies and vendors to swiftly modify software structure with new release updates (Rizzi and Zamboni, 1999). One of the major features of ERP software is the integration between modules, data storing/retrieving processes, and management and analysis functionalities (Davenport, 1998; Hoffman, 1998). ERP provides the same functionalities of previous stand-alone systems while allowing access to enterprise-wide information by employees throughout the entire company on a controlled basis.

### *1.2. Reasons firms adopt ERP*

Many firms that implement ERP systems strive to reduce redundancy and inconsistency in data through the creation and maintenance of a central database of corporate information. Errors are reduced and employees have access to current information for decision-making. Data reentry errors and omissions from one business process to the next are eliminated (Rizzi and Zamboni, 1999; Latamore, 2000). The ERP architecture also facilitates integration across different applications (i.e., information sharing across business processes) supporting concurrent and automatic updates, without the need for manual intervention. This reduces labor costs, bureaucracy, and errors (Latamore, 2000). Given these features of ERP, firms implementing ERP systems should experience an overall reduction in cost and a general improvement in decision-making activities.

Anecdotal evidence also suggests that firms expect ERP systems to deliver improved firm performance. Specifically, firms expect ERP systems to result in (Brown, 1997;

Davenport, 2000; Gilbert, 2000; Glover et al., 1999; Knorr, 1999; Rizzi and Zamboni, 1999; Wah, 2000):

- Reduced asset bases and costs, enhanced decision support, more accurate and timely information, reduced financial cycles, and increased procurement leverage;
- Increased customer satisfaction through integration and consistency;
- Conversion to Year 2000[2] compliant software;
- Response to pressure from trading partners who have already converted their systems;
- Globally integrated information access across the enterprise and supply chain;
- Enabling e-business; or
- Flexibility to change quickly and configure the business in response to a changing marketplace while making tacit process knowledge explicit.

Consulting survey results of Fortune 500 companies suggest perceived tangible and intangible benefits from ERP of cost reductions and revenue improvements including (but not limited to) inventory and personnel reduction, productivity and order management improvement, improved information, improved processes, and improved customer responsiveness (Benchmarking Partners, 1998). Finally, many firms have announced performance improvements attributed to their ERP system (see Appendix A, Panel A).

### *1.3. The high cost and complexity of ERP implementations*

While managers may strive for financial improvements from ERP adoption, firms may experience adverse financial effects. A typical ERP implementation is complex. Organizations have had a great deal of difficulty in integrating the ERP software with the hardware, operating systems, database management systems, and telecommunications suited to their organizational needs (Markus and Tanis, 2000). Further, additional complexity arises because the ERP software implementation results in changes throughout the division or the entire firm. ERP implementations require substantial investments in software and hardware, direct implementation costs, and training for system users (Davenport, 2000; Wortmann, 1998). To address this high cost and complexity, ERP vendors developed preset software parameters based on ‘‘best practice’’ models within a given industry (Schragenheim, 2000). However, this approach adds to the complexity by introducing rigidity to the implementation process, often causing project delays and failures (Williamson, 1997; Knorr, 1999; Wortmann, 1998). ERP implementations can have lengthy project windows of 3 to 5 years (Davenport, 2000), contributing to higher costs.

[2] This problem refers to old information systems being programmed to handle dates as two-digit numbers, i.e., ’98, ’99, ’00. This would cause the computer to confuse ’00 as the year 1900 or 2000. ERP systems use a four-digit number to eliminate this ambiguity and they are compliant with recognizing the date of the year 2000. This was a critical issue during the period over which the data were collected.

Additionally, ERP implementations are often performed along with business process reengineering (Davenport, 2000; Grabski et al., 2000; Wortmann, 1998). Some firms wanting to reengineer use ERP as the vehicle to accomplish this (Grabski et al., 2000). While this study is focused on the effect of ERP on firm performance, the separate effect of reengineering business process cannot be disentangled. An ineffective and unsuccessful process reengineering project could also contribute to lost performance gains including negative financial returns. These adverse results are not unusual as many firms have announced negative results attributed to their ERP implementation (see Appendix A, Panel B).

Successful ERP implementations may exhibit negative effects as many tasks are automated and positions eliminated. Workers reengineered out of a position and redeployed within the company may enter a grieving process resulting in low productivity (Arnold et al., 2000). In addition, performing process reegineering assumes current processes are insufficient and changes them, but the current processes may be appropriate (and best) for that organization. Finally, the ''best practice'' models used by ERP vendors are based on successful methods from prior decades and might not anticipate the future needs of evolving organizations (Arnold et al., 2000). ERP models focus on order and streamlined processes, which may stifle creativity and innovation (Arnold et al., 2000). ERP systems also impose a hierarchical organization with a command and control perspective, which may be unsuitable for a given organization (Davenport, 2000).

Finally, with the adoption of ERP systems, information errors are no longer confined to one area of the company. Errors maintained within the ERP system are propagated throughout the entire business (Lynn and Madison, 2000). Managers and technology staff are both responsible for ensuring data integrity and appropriateness of processes within ERP systems. An ERP system with poor information quality and inappropriate processes guarantees that more wrong answers look prettier and they are accessed faster by decision-makers (Lynn and Madison, 2000). Decisions based on error-filled data may lead to inefficient and ineffective management of the firm. Thus, while the promise of ERP systems to provide firm performance improvements exist, other factors exist that could result in significant economic losses.

This study empirically examines the influence of ERP technology on firm performance. However, given the recency of the development of ERP systems, few firms have long postimplementation time horizons resulting in a limited potential sample. Nonetheless, this paper introduces theory-based predictions and provides incipient evidence on ERP systems and firm performance.

## 2. Hypotheses development

The relevant literature provides ambiguity for predicting the impact of information systems on firm performance (see Brynjolfsson and Yang, 1996; Bharadwaj et al., 2000 for reviews of this literature). While many studies found technology associated with decreases in worker productivity (Roach, 1991, Strassmann, 1997), other evidence provides encouraging results of a productivity payoff. Specifically, the technology coordination cost

literature suggests that information systems are expected to contribute to a firm's economizing by:

1. Increasing scale efficiencies of firm operations (Mitra and Chaya, 1996; Harris and Katz, 1991);
2. Processing business transactions effectively (Malone et al., 1987; Johnston and Lawrence, 1988);
3. Collecting and disseminating timely information for decision-making (Simon, 1955);
4. Monitoring and recording employee performance effectively (Zmud and Apple, 1992); and
5. Maintaining records of business functions within the organization or maintaining communication channels with lower cost (Cash and Konsynski, 1985).

Section 2.1 examines how an ERP system should affect internal firm operations by applying economic and industrial organization theories to better understand this relationship. Internal operations can be broken down into production and coordination costs (Malone et al., 1987). Since ERP systems are not production automation tools, they are not expected to impact production costs.

To examine how ERP is expected to affect specific internal and external coordination costs components, the organization cost categories defined by Gurbaxani and Whang (1991) are utilized (see Table 1). The coordination cost categories do not have an isomorphic matching with reported financial statement categories. Consequently, the paper first discusses how coordination costs are affected by ERP systems. Then, these coordination costs are aggregated and matched to the appropriate financial statement categories and formal hypotheses are developed.

### *2.1. Internal coordination costs — agency costs*

Jensen and Meckling (1973) proposed that a firm represents a set of agency contracts under which a principal (entrepreneur) employs agents (employees) to perform some service on his/her behalf. A strong assumption is that an agent is utility-maximizing, preferring more rewards and less effort, but pays no regard to nonpecuniary benefits. Agency costs are defined as the costs incurred due to discrepancies between the objectives of the principal and those of agents. Agency costs are incurred by the principal to deter shirking by the agent. Along with the costs of developing the appropriate incentive contracts, these costs include monitoring the agent's work efforts, non-value-added agent tasks for reporting and documenting activities, and welfare loss from inefficiencies and miscommunications with the agent. With respect to technology, information systems change the cost of acquiring information about agent's behavior.

Specific to ERP, implementing the software should reduce *monitoring costs* by automating process steps and by providing an electronic trail of employee responsibility (Gurbaxani and Whang, 1991). Given universal access to one database, managers can efficiently and effectively review employee actions in a timely manner. This, in turn,

Table 1
Information system effects on economic performance of the firm

| Cost categories (Gurbaxani and Whang, 1991) | ERP effects on firm costs | Related cost category found in Compustat database |
|---|---|---|
| *Internal coordination costs* | | |
| Agency costs | | |
| • Monitoring costs | Decreases administrative monitoring costs<br>Decreases cost of defects and errors in product and information | Decrease in SG&A;<br>Decrease in COGS |
| • | | |

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should decrease the need for additional monitoring activities, reduce defects and human errors, and eliminate the need for investigation and rework employees. Selling, general, and administrative expenses are period costs, 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 operations (Kieso and Weygandt, 1989). Cost of goods sold 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 (Kieso and Weygandt, 1989).

In general, ERP systems should streamline monitoring activities and decrease errors, as such, we expect to see a reduction in general and administrative costs of running the company. Within the factory, ERP should also decrease the costs of monitoring production employees reducing the need for factory supervisory labor, therefore, we expect to see a reduction in cost of goods sold.

*Bonding costs* involve the employee reporting their actions to their employer, which is time consuming and effort-intensive (Gurbaxani and Whang, 1991). An ERP package should automate the process and provide easier access to reporting activities for employees in sales and back office operations, reducing selling, general and administrative costs, and for production labor and factory supervisory employees, reducing cost of goods sold.

*Residual loss* is associated with principal specific welfare losses from dealing with agents (Gurbaxani and Whang, 1991). These costs are not expected to be influenced directly by an ERP system.

Few empirical studies have examined technology's effect on agency costs, although some studies address internal coordination costs in general. Research has found technology investments associated with a decrease in total costs (Alpar and Kim, 1990), and internal coordination costs (Shin, 1999). However, other research found higher technology investment associated with lower production costs and total costs, but higher overhead costs (Mitra and Chaya, 1996).

### *2.2. Internal coordination costs — decision information costs*

Decision rights theory proposes that the employees at the bottom of the organizational hierarchy generally have better access to local information, which is continually subject to change (Jensen and Meckling, 1992). If all the decisions are to be made by top managers to reduce agency costs, there is a need to process information upward in the hierarchy, resulting in information-processing costs, i.e., costs of communication, miscommunication, and delays in communication. Decision-making without relevant information can lead to suboptimal decisions. Decision information costs increase as a decision right is moved higher in the hierarchy, away from where information is most easily available. However, placing decision rights at the bottom of the hierarchy is problematic, since the objectives of the principal and the agents may be inconsistent. Decision right should be located where the combined decision information and agency costs are minimized (Jensen and Meckling, 1992). With respect to technology, information systems change the costs of acquiring, sharing, and distributing the information surrounding the decision itself.

Since ERP technology is expected to provide more timely and accurate enterprise-wide information for decision-making, *information-processing costs* (communication and documentation) and *opportunity costs due to poor information* should be reduced. Cost reductions should be evident in both selling, general, and administrative costs as well as in the overhead associated with cost of goods sold. Also, assuming rationality on the managers' part, better information should lead to cost minimizing and revenue maximizing actions, which should be reflected in reductions in selling, general, and administrative, and cost of goods sold, as well as increases in revenues. Some empirical work indirectly addresses the impact of technology on decision information costs, finding technology spending was associated with improved

intermediate decision variables (Barua et al., 1995), the complexity and uncertainty regarding specific activities (Ragowshy et al., 1996), and increases in revenue generation (Venkatraman and Zaheer, 1990).

### *2.3. External coordination costs — transaction costs*

Agency and decision information theory focuses on organizational problems that arise from informational considerations. Transaction cost economics posits 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.

High market transaction costs are often associated with firm-specific assets, where long-term contracting is required to prevent the other party from acting opportunistically (Williamson, 1981). However, a long-term contract may not be a stable solution when the degree of uncertainty is high. In order to prevent one party from exploiting the other, such a contract must account for future contingencies, which can be difficult to predict. Incompletely specified contracts leave the negotiating parties vulnerable to opportunism. One solution is for contracting firms to integrate vertically, since a firm is relatively more capable of immediately and costlessly restructuring decision rights, redeploying resources, and resolving disputes. External sourcing of an input factor may entail extra costs in obtaining market information, communicating with geographically separated vendors, transporting goods, and holding inventories (Gurbaxani and Whang, 1991). These are also market transaction costs that could be reduced by producing the factor in-house. Accordingly, 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. Technology can directly reduce market transaction costs of operations and contracting by providing a cost-effective means to access market information and process transactions as well as facilitating tighter interfirm links through information sharing and mutual monitoring.

For external coordination costs, an ERP system is expected to maintain accurate databases

(Gurbaxani and Whang, 1991), an ERP package is not predicted to have a material impact on the costs of performing these activities.

### 2.4. ERP effects on firm performance over time

The third column of Table 1 specifies the ERP system's effects on costs and revenues to the associated category found in company financial statements. Given the all-encompassing enterprise-wide nature of ERP adoptions, effects should be large enough to be reflected in financial statement values. Prior research has indicated that a time lag is necessary for capturing the performance improvements from information technology (Brynjolfsson, 1993; Brynjolfsson and Hitt, 1993). Employees need time to coinvent through their own experimentation and discovery, to find ways for the new system to support their work (Bresnahan and Greenstein, 1996). However, cost reduction gains tend to be short-lived as competition acquires the cost-saving technology and demand for the cheaper product plateaus (Payson, 1998) or savings are competed away to benefit consumers (Brynjolfsson and Hitt, 1996). Thus, this study examines the changes in firm performance from 1 year before to 1, 2, and 3 years after ERP implementation. While a longer time horizon after implementation analysis is preferred (Knorr, 1999; Wah, 2000), no 4- or 5-year postimplementation financial data are publicly available for 48% of the sample. Using a longer time horizon for analysis is infeasible. The following hypotheses examine pooled data across modules and across vendors, before and 1, 2, and 3 years after the implementation of the ERP system.

While other variables have been examined (i.e., return on assets and Tobin's $q$; Bharadwaj et al., 2000), our predictions have focused on specific elements of costs and revenues that have been used in prior studies (see Mitra and Chaya, 1996). Formally, we examine the following hypotheses (all hypotheses in this paper are stated in their alternate form). Due to the enterprise-wide nature of ERP and its predicted association with decreased monitoring, bonding, information processing, poor information, and operational costs (see Table 1), as well as improved decision-making and increasing revenues, the first hypothesis is:

*Hypothesis 1:* $\text{SG\&A/Revenues}_{\text{POST}} < \text{SG\&A/Revenues}_{\text{PRE}}$

where SG&A refers to selling, general, and administrative costs, and PRE and POST refer to costs before and after ERP implementation, respectively. POST represents separate analysis of 1, 2, and 3 years after the ERP implementation.

Given the influence of ERP on administrative monitoring and reporting costs of production personnel, as well as improved production processing decision-making, the next hypothesis is:

*Hypothesis 2:* $\text{COGS/Revenues}_{\text{POST}} < \text{COGS/Revenues}_{\text{PRE}}$

where COGS refers to cost of goods sold, and PRE and POST refer to costs before and after ERP implementation, respectively. POST represents separate analysis of 1, 2, and 3 years after the ERP implementation.

Many managers believe that measuring return in relation to investment provides the ultimate test of profitability. One popular measure that emphasizes an absolute amount of income rather than a percentage rate of return is residual income (RI), defined as net operating income less "imputed" interest (Horngren et al., 1999). However, RI is based on each firm's "imputed" interest, which refers to its cost of capital. These values are generally unavailable from public sources. In any event, we compute this value, assuming a 12% cost of capital for each firm. Based on the improvements to firm performance from ERP adoption, we hypothesize:

*Hypothesis 3:* $RI_{POST} > RI_{PRE}$

where RI refers to residual income and PRE and POST refer to costs before and after ERP implementation, respectively. POST represents separate analysis of 1, 2, and 3 years after the ERP implementation.

Finally, to fully understand the association of ERP and firm performance, ERP is predicted to automate clerical tasks resulting in a reduction in employees. While the 1990s were associated with a general downsizing of firms, ERP should enable the firm to achieve this without sacrificing revenue-generating activities. Therefore, the final hypothesis includes:

*Hyphothesis 4:* Number of employees/$Revenues_{POST}$ < Number of employees/$Revenues_{PRE}$

where PRE and POST refer to costs before and after ERP implementation, respectively. POST represents separate analysis of 1, 2, and 3 years after the ERP implementation.

While not specifically hypothesized, given prior suggestions of time lags in observing performance effects (Brynjolfsson, 1993; Brynjolfsson and Hitt, 1993), performance improvements are expected to become more evident in later years.

## 3. Sample selection and validation

### 3.1. Sample selection

The sample was selected by identifying firms that publicly disclosed ERP adoption from 1980 to 1997 in PR Newswire press releases in Lexis–Nexus and in the Wall Street Journal. Appendix B includes exact copies of actual press release working used to identify sample firms. The initial sample was limited to firms that implemented one of the top five application vendor packages:[3] SAP, PeopleSoft, Oracle, Baan, and J.D. Edwards. An initial sample was identified by performing key word searches in the databases, using search strings such as

[3] Revenues are based on 1997 software license and maintenance revenues: SAP with US$2250 million in revenues, PeopleSoft with US$705 million, Oracle with US$699 million, Baan with US$432 million, and J.D. Edwards with US$320 million (Xenakis, 1999). Computer Associates with US$435 million in revenues was not included in this study as they are considered a value-added reseller and not a direct software vendor.

Table 2
Descriptive statistics of sample firms

Panel A: Distribution of 50 sample firms by implementation date

| Year | Number of implementations | |
|---|---|---|
| *Implementation duration less than or equal to 1 year* | | |
| 1989 | 0 | |
| 1990 | 0 | |
| 1991 | 0 | |
| 1992 | 0 | |
| 1993 | 1 | |
| 1994 | 3 | |
| 1995 | 3 | |
| 1996 | 10 | |
| 1997 | 10 | |
| 1 year total | 27 | 54% |
| *Implementation duration equal to 2 years* | | |
| 1993 and 1994 | 2 | |
| 1994 and 1995 | 3 | |
| 1995 and 1996 | 9 | |
| 1996 and 1997 | 9 | |
| 2 years total | 23 | 46% |
| Total of all implementations | 50 | 100% |

Panel B: Distribution of 50 sample firms by SIC code

| SIC | Number of sample companies |
|---|---|
| 10 | 1 |
| 15 | 1 |
| 20 | 1 |
| 21 | 1 |
| 23 | 1 |
| 25 | 1 |
| 28 | 6 |
| 29 | 2 |
| 30 | 1 |
| 33 | 1 |
| 34 | 1 |
| 36 | 7 |
| 37 | 10 |
| 38 | 3 |
| 39 | 1 |
| 48 | 3 |
| 49 | 3 |
| 51 | 1 |
| 60 | 2 |
| 68 | 1 |
| 74 | 2 |
| Total sample companies | 50 |

Table 3
Descriptive statistics of firm sample

| Item | Mean (US$000) | Median (US$000) | S.D. (US$000) |
|---|---|---|---|
| *Panel A: Distribution of sample data — reported values* | | | |
| Net sales | 11,980.26 | 2,674.70 | 26,116.38 |
| Total assets | 14,507.71 | 3,605.21 | 33,823.12 |
| Costs | | | |
| 4-year average before implementation ($n=50$) | | | |
| Cost of goods sold | 8,041.15 | 1,561.64 | 20,227.66 |
| Selling, general, and administrative | 2,073.50 | 474.70 | 4,352.16 |
| Employees | 63.39 | 16.30 | 125.11 |
| 1 year before implementation ($n=50$) | | | |
| Cost of goods sold | 8,283.18 | 1,652.10 | 21,204.48 |
| Selling, general, and administrative | 2,313.77 | 517.50 | 4,640.50 |
| Revenues | 8,447.71 | 1,677.71 | 20,700.01 |
| Employees | 62.11 | 17.06 | 119.30 |
| 1 year after implementation ($n=50$) | | | |
| Cost of goods sold | 8,447.71 | 1,677.71 | 20,700.01 |
| Selling, general, and administrative | 2,489.58 | 649.98 | 4,495.61 |
| Revenues | 8,989.01 | 1,883.00 | 22,131.89 |
| Employees | 58.71 | 18.38 | 107.87 |
| 2 years after implementation ($n=48$) | | | |
| Cost of goods sold | 8,989.01 | 1,883.00 | 22,131.89 |
| Selling, general, and administrative | 2,599.55 | 678.45 | 4,393.50 |
| Revenues | 13,528.97 | 3,074.81 | 27,797.67 |
| Employees | 55.53 | 20.40 | 88.66 |
| 3 years after implementation ($n=26$) | | | |
| Cost of goods sold | 7,894.53 | 3,278.00 | 11,268.66 |
| Selling, general, and administrative | 2,485.72 | 830.90 | 4,420.67 |
| Revenues | 12,195.82 | 4,665.52 | 18,099.37 |
| Employees | 56.89 | 23.00 | 87.45 |
| *Panel B: Distribution of sample data — % of sales* | | | |
| Cost as a percentage of sales | | | |
| 1 year before implementation ($n=50$) | | | |
| Cost of goods sold | 59.0% | 61.4% | 18.0% |
| Selling, general, and administrative | 24.8% | 24.3% | 12.8% |
| Employees | 0.556% | 0.553% | 0.233% |
| 1 year after implementation ($n=50$) | | | |
| Cost of goods sold | 60.6% | 63.6% | 19.2% |
| Selling, general, and administrative | 26.1% | 26.5% | 12.5% |
| Employees | 0.540% | 0.566% | 0.215% |
| 2 years after implementation ($n=48$) | | | |
| Cost of goods sold | 59.7% | 61.0% | 18.0% |
| Selling, general, and administrative | 26.0% | 24.4% | 12.3% |
| Employees | 0.529% | 0.493% | 0.260% |
| 3 years after implementation ($n=26$) | | | |
| Cost of goods sold | 62.0% | 63.1% | 14.2% |
| Selling, general, and administrative | 23.1% | 21.9% | 11.8% |
| Employees | 0.480% | 0.464% | 0.184% |

"implement* VENDOR," "install* VENDOR" for each vendor name, where the wildcard symbol " * " matches any ending of the verb, i.e., implementation, implemented, implementing, etc. These initial samples were reduced to the final sample of 54 firms using the following data filters:

1. The specific year when their ERP implementation started or ended was identified;
2. Cost and revenue information was available through the COMPUSTAT database — captured and calculated as continuous variables for annual ratio of cost to revenues; and
3. ERP implementation must have finished before December 1997.

The second restriction concerns the variables used in the study, calculated as each firm's selling, general, and administrative costs, the cost of goods sold, and number of employees as a percentage of revenues. Firm performance is defined as the ratio of cost to revenues in order to capture both the cost-reduction and revenue-enhancing effects of ERP systems on the firm. This approach also controls for firm size. The third restriction was imposed because postimplementation cost information was unavailable for implementations occurring after December 1997.

### 3.2. Sample validation

The annual reports for the year before, during, and each of 3 years after implementation were reviewed for each of the 54 companies to validate information from the public announcement sources. No conflicting information was found.

Four firms were deemed outliers and removed from the sample. These firms had undergone exceptional changes during the time period of this study (i.e., made major acquisitions, etc.) and these changes, not the ERP system, could potentially drive the firm's differences in performance ratios or confound the effects of the ERP system. Pairwise comparisons are employed to control for firm and industry differences.

### 3.3. Descriptive statistics

The distribution of ERP adoption by firms by implementation year is presented in Panel A of Table 2. Of the sample firms, 58% (29 of 50) implemented ERP taking 1 (21) or 2 (8) years between 1996 and 1997. Eighty-two percent (41 of 50) implemented ERP taking 1 (24) or 2 (17) years between 1995 and 1997. The average implementation length was 1.5 years. Of the sample firms, 54% implemented SAP, 40% implemented Oracle, while 4% implemented PeopleSoft and the remaining 2% implemented Baan. This sample distribution is consistent with analyst reports on ERP vendor market share for 1996,[4] thus the representation of ERP

[4] For 1999, ERP market share breakdown: SAP at 51%, Oracle at 24%, PeopleSoft at 12%, J.D. Edwards at 8%, and Baan at 5% (Gilbert, 2000).

vendors included in the sample is consistent with the market share held by the vendors as of the time period covered by the study.

The industry distribution of ERP firms is in Panel B of Table 2. The main industries represented by sample firms are motor vehicles and accessories (SIC = 37), which comprise 20% of the total (10 of 50); electronics (SIC = 36), which comprise 14% of the total (7 of 50); and chemical and allied products (SIC = 28), which comprise 12% (6 of 50). The remaining firms are evenly distributed across a variety of industries.

As reported in the first two lines of Panel A Table 3, the mean (median) year prior to implementation-year sales for the set of sample firms is US$12 million (US$2.7 million) and total assets of US$14.5 million (US$3.6 million). Also, the mean and median costs 1 year before, average of the 4 years before, and 1, 2, and 3 years after implementation are provided. The distribution of sample data for cost as a percentage of sales is listed in Panel B of Table 3.

Financial values were not adjusted for inflation as the inflation rate for the study period of 1993–1999 experienced modest to low inflation rates (www.globalfindata.com, 2000). Financial information of each firm during the year(s) of implementation is disregarded, since it reflects the intervention event interrupting the time series. According to accounting standards, preliminary project and immediate postimplementation costs of getting the ERP implementation up and running are expensed as incurred.[5] The year before ERP implementation is used to capture stable costs before implementation (as discussed below, results are not significantly different when a 4-year preimplementation average is used). Actual ERP implementation costs are amortized, replacing preimplementation costs of the multiple systems that were eliminated.

## 4. Results

### *4.1. ERP and firm performance*

To test for significant changes in the performance ratios, a repeated measures within-subjects multivariate test was used initially. However, the repeated measures test eliminates firms without 3 years of data reducing the sample for all analyses to 20 data points. As such, the small sample size disrupts and confounds findings. Therefore, paired samples *t* tests were performed (see Table 4) maintaining the maximum number of sample firms for each individual test, which compares performance ratios after vs. before ERP implementation, while minimizing the variance within the individual firm. Paired samples *t* tests also control for firm and industry effects.

[5] Under AICPA Statement of Position 98-1, which clarifies FAS 86, an ERP implementation project covers three phases: (1) Preliminary Project Stage where costs are expensed as incurred, (2) Application Development Stage, which includes software design, interfaces, coding, new hardware and software installation and testing of the system, and costs should be capitalized, and (3) Postimplementation/Operation Stage, which including user training where costs are expensed as incurred.

Table 4
Pairwise sample $t$ test results for difference in ratio, after vs. year before adoption for ERP adopting firms [$t$ statistic ($P$ value)]

| | Comparison of ratio after vs. before ERP implementation | | | |
|---|---|---|---|---|
| | SG&A/ revenues | COGS/ revenues | Number employees/ revenues | Residual income at 12% |
| 1 year after vs. year before | 1.470 (0.07) $n=45$ | 1.312 (0.10) $n=49$ | −2.024 (0.02)* $n=46$ | 0.147 (0.44) $n=51$ |
| 2 years after vs. year before | 1.195 (0.12) $n=44$ | 0.696 (0.25) $n=48$ | −3.018 (0.00)* $n=45$ | 0.113 (0.46) $n=50$ |
| 3 years after vs. year before | 0.059 (0.48) $n=23$ | −1.702 (0.05)* $n=26$ | −3.372 (0.00)* $n=42$ | 0.535 (30) $n=27$ |

Sample size varies due to the nonavailability of postimplementation data for all sample firms.
* $t$ value significant at .05 level, one-tail.

Results indicate that ERP implementation is associated with no significant decrease in selling, general, and administrative costs divided by revenues 1 (mean = 0.29), 2 (mean = 0.28), or 3 (mean = 0.23) years ($t = 1.470$, n.s.; $t = 1.195$, n.s.; $t = 0.059$, n.s.) after implementation over the year prior to implementation (mean = 0.25). Thus, Hypothesis 1 is not supported.

ERP implementations are not found to be associated with a significant decrease ($t = 1.470$, n.s.; $t = 0.696$, n.s.) in cost of goods sold divided by revenues 1 year (mean = 0.61) or 2 years (mean = 0.60) after implementation over the year prior to implementation (mean = 0.59). However, ERP implementation is found to be associated with a significant decrease ($t = -1.702$, $P$=.05) in cost of goods sold divided by revenues for 3 years after implementation (mean = 0.62). Therefore, Hypothesis 2 is partially supported.

ERP implementation is not found to be associated with increases in RI 1 ($t = 0.147$, $P$ = n.s.), 2 ($t = 0.113$, $P$ = n.s.), or 3 ($t = 0.535$, $P$ = n.s.) years after ERP implementation. As a result, Hypothesis 3 is not supported.

The results do indicate that ERP implementations are associated with a decrease in the number of employees needed to support a given level of revenue for 1 ($t = -2.024$, $P$=.02), 2 ($t = -3.018$, $P$=.00), and 3 ($t = -3.372$, $P$=.00) years after implementation. This is reflected in the number of employees divided by revenues prior to implementation (mean = 0.006) over the year after (mean = 0.005), 2 years after (mean = 0.005), and 3 years after (mean = 0.004) implementation of ERP. The results indicate that Hypothesis 4 is supported for each of 3 years following an ERP implementation, illustrating an improvement in firm performance regarding the labor force.

Statistical analysis revealed no significant trends in firm performance ratios for the years and firms covered by this study. Results presented do not change if the performance ratio values of the year prior to ERP implementation are replaced by a 4-year average of cost as a percentage of revenues prior to implementation for all performance ratio measures. Additional analysis indicates no significant differences in performance ratios between types of firms when partitioned as manufacturing ($n = 39$) vs. service ($n = 11$).

## 5. Conclusion

### 5.1. Summary of findings

Based on the sample of 50 companies implementing ERP packages from 1993 to 1997, results indicate no significant change in costs as a percentage of revenue until 3 years after the implementation of the ERP system, and then a significant decrease in costs only for cost of goods sold as a percentage of sales. There were no significant decreases associated with selling, general, and administrative costs scaled by revenues, nor was there any improvement in RI. However, there was a significant decrease in the number of employees as a percentage of revenue all 3 years after ERP implementation. While inconclusive, this paradox suggests additional complexities surround ERP technology. To fully understand the results, the limitations associated with the study must be examined.

### 5.2. Limitations of results

Given that industry experts predict a 4- to 5-year return for ERP implementations (Knorr, 1999; Wah, 2000; Wortmann, 1998), the 3-year longitudinal window may be insufficient to capture the effects of ERP on firm performance. The lack of long-term postimplementation public financial data for 82% of the sample implementations made it infeasible to use a longer time horizon for analysis. Thus, the benefits of ERP may not be apparent until 4 to 5 years after implementation. Future research studies on ERP should lengthen the post-implementation window to ensure an adequate longitudinal timeframe for observing the impacts of ERP on firm performance. Further, these ERP systems studied might only provide the necessary infrastructure for improvements, and the real benefits will result when the ''bolt-on'' packages such as customer relationship management and advanced planning systems are utilized. That is, ERP systems are necessary but not sufficient for significant improvement in financial performance.

Many firms implementing ERP simultaneously perform process reengineering. Thus, reengineering business processes could cause the effects attributed to ERP on firm performance. However, the ERP implementation could have brought about the process reengineering, which in turn, changed firm performance. The ERP implementation, either directly or indirectly through process reengineering, had an impact on firm performance. Future studies may need to capture the separate effects of process reengineering vs. ERP adoption.

While four firms were eliminated due to exceptional changes in their businesses, this study was unable to control for additional initiatives (i.e., JIT, TQM, etc.) or other firm or industry events that could impact firm performance simultaneously with the ERP implementation. Even though industry experts and ERP implementation consultants informed us that implementing ERP is an enormous task and concurrent implementation of other initiatives would be extremely difficult, these initiatives could be taking place. Future research should capture these initiatives via a survey instrument and control for their effect on firm performance.

Additionally, macroeconomic influences were not controlled for in this study reducing the ability to isolate financial effect from adopting ERP. Future studies should employ a control sample of firms matched on industry membership and size that have not adopted ERP. Comparison of financial performance between these groups would reveal differences attributable to ERP adoption.

Another limitation of this study was the additional value associated with capturing and controlling for variables reflecting the level of success of ERP implementations. Brynjolfsson and Hitt (1998) found that purchasing computerized equipment was the smallest part of the overall cost of creating a new manufacturing system, while the biggest costs were in changing the organization. It could be that all the sample firms had unsuccessful implementations, including unsuccessful organizational change management, inadequate technology capabilities, etc., and these factors have confounded the ability to examine whether the ERP system has affected firm performance. Thus, future studies may need to control for implementation and organizational characteristics to better understand the impacts of ERP.

Finally, the sample included firms that voluntarily disclosed the announcements. As a result, the sample may be biased in that it contains only those ERP implementations that firms wish to make known. Given this potential bias, a reduction in costs or increase in revenues is to be expected in the full sample of ERP implementations. That the opposite is found is evidence against such a bias in the sample. Future studies may need to employ survey methods and random sampling of target companies to guard against potential bias in their sample of ERP implementors.

### *5.3. Lessons from the study*

Initial empirical findings indicate a paradox where firms having fewer employees supporting more revenue simultaneously experience higher cost-to-revenue ratios after their ERP implementation. While the exact reasons for this are unknown without more detailed research, this section of the paper explores some competing and complementary potential explanations for the phenomena observed in this study.

Because of the mammoth expanse of ERP and difficulties in implementation, firms could be reducing costs by streamlining processing and eliminating clerical duties that are automated, but increasing costs from hiring expensive ERP computer engineers for post-implementation maintenance. In 1998, the premium paid for SAP skills (the ERP vendor with greatest market share) above regular salary levels was 39% for information technology consultants and contractors and 19% for information technology permanent staff (Spain, 1997). After making large investments in ERP, companies may be unwilling to divest of the skills needed to keep these vital systems running. Firms might be trading the long-term gains from eliminating clerical jobs and improving decision-making for short-term high costs in consulting and systems staffs to support on-going ERP system maintenance.

Another reason that costs as a percentage of revenue increase after implementing an ERP system is that on-going fixes and fine-tuning of installations may continue past the officially stated implementation ending date. The Standish Group International, a research advisory

company, estimates 90% of ERP projects run late (Williamson, 1997). Costs captured after the implementation end date may reflect additional implementation costs causing inflated selling, general, and administrative costs and cost of goods sold values. This would cause the cost as a percentage of revenue value the first year after implementation to be abnormally high.

Another explanation could be that organizational culture and human issues initially block the performance gains from ERP. It takes time for employees to understand and experiment with new technology before they can reap the rewards of using it (Bresnahan and Greenstein, 1996; Brynjolfsson and Hitt, 1998). Thus, during post-ERP implementation, inefficiencies caused by people eliminated the performance gains created by installing the ERP system, and after the organizational issues are resolved, the rewards of ERP surface. This might be observed by controlling for these organizational factors or extending the longitudinal window for analysis.

Finally, after an extensive economic investigation of how technology spending affects firm productivity, Hitt and Brynjolfsson (1996) find that firms spending more on technology are more productive but do not capture the resulting profits. These profits (benefits of increased productivity) are passed on to the consumer. Thus, firms adopting ERP in a competitive market pass on the benefits of lower costs per dollar of revenue to their customers.

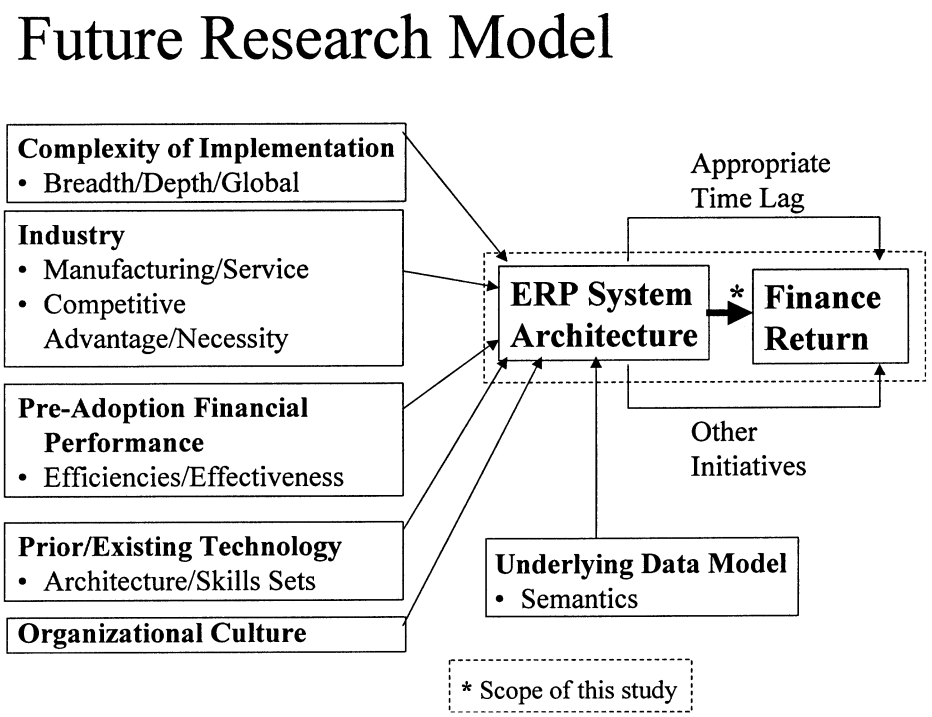


Fig. 1. Future ERP research model.

### 5.4. Future research directions

The impact on firm performance of ERP implementations within companies from 1993 to 1997 was examined. This new technology was predicted to (1) reduce costs by improving efficiencies through computerization; and (2) enhance decision-making by providing more accurate and timely data through individual access to enterprise-wide information. Both of these effects were predicted to improve firm performance. However, the results suggest no significant improvements in firm performance ratios except for 3 years after the implementation for cost of goods sold scaled by revenues. To fully explain these results, future research is needed to clarify and examine the multitude of factors affecting the ERP and firm performance relationship. Based on the findings and limitations in this study, a model of future ERP research directions was developed (see Fig. 1).

This research introduced theory-based predictions and incipient evidence on the limited connection between ERP system architecture and firm performance (see the relationship connection designated by " * " in Fig. 1). Additional in-depth research is needed to study other important constructs influencing the relationship of an ERP system and financial returns while controlling for other firm and industry initiatives and lengthening the longitudinal window. As illustrated in the proposed ERP research model, the ERP arena is replete with research opportunities.

## Appendix A. Examples of company performance and ERP

### A.1. Panel A: stories by firms implementing ERP — positive impacts

- Arizona Electric Power Corporation implemented J.D. Edwards ERP software and reduced month-end closings from 38 to 9 days, decreased invoice processing from 30 to 2.5 days, and reduced annual material and supply costs by $350,000 (www.jdedwards.com, 2000).
- Hoechst Marion Roussel implemented SAP and found greater flexibility and accelerated decision-making at all levels of the firm (www.sap-ag.de, 1997).
- Westcoast Energy Inc. found after implementing SAP, its average materials procurement went from 23 to 12 days and financial month-end closing went from 12 to 6.5 days. Westcoast has projected its SAP implementation has saved $2.5 million per year in bottom-line cost savings from the elimination of non-value-added steps in their business processes (www.sap-ag.de, 1997).
- Purina Mills Inc. stated that its ERP lead to system consolidation of many business processes at their headquarters. As such, they reduced headcount by eliminating redundant staff in branch offices and in the accounting function, leading to a 43 percent reduction in headcount costs (Wah, 2000).
- Peak USA Energy Services says ERP has led to additional revenues and costs savings of about $900,000 annually (Wah, 2000).

*A.2. Panel B: stories by firms implementing ERP — negative impacts*

• Hershey Foods' $112 million ERP software from SAP fouled up the company's candy shipments for Halloween in October 1999. Hershey announced a 19% drop in 3rd-quarter profits because of order-processing problems, which will likely result in lost market share (Stedman, 1999; Boudette, 1999).

• Whirlpool said problems with a new SAP system and a high volume of orders combined to delay shipments of appliances to many distributors and retailers (Boudette, 1999).

• Medline is suing Andersen Consulting in connection with Andersen's ERP implementation. Medline charged that Andersen failed to configure the ERP systems appropriately (Stein, 1997).

• Hydro Agri's fertilizer stores experienced an increase from 20 to 90 seconds in order processing time after implementing SAP's ERP package (Stedman, 1998).

• A-dec Inc. found calls to their help desk increased 64% after implementing Baan's financial and manufacturing modules (Stedman, 1998).

## Appendix B. Examples of press release of ERP adoption

*B.1. News release/announcement*

HEADLINE: Plaut Consulting Leads Accelerated SAP R/3 Implementation at Cabletron Systems

July 21, 1997

Networking leader is one of the first in U.S. to support 1,100 users utilizing Windows NT applications servers and an Oracle database. Multisite, enterprisewide R/3 implementation is on time and within budget.

Plaut Consulting Inc. announced today that its management consultants led a successful 12-month implementation of SAP's R/3 integrated business application solution for Cabletron Systems, a leading manufacturer of computer networking systems and services. Cabletron completed its first quarter-end close on the new system in June.

According to Klaus Schottenhamel, President of Plaut Consulting, "This fast and effective R/3 implementation illustrates not only that Plaut can manage projects of this size and scope within budget and on time, but it also showcases our ability to successfully partner with multiple parties to get the job done."

Data Gathered:

| | |
|---|---|
| • Client: | Cabletron Systems |
| • Implementation window: | 12 months ended July 1997 |
| • Years of implementation: | Calendar year 1996 and 1997 |
| • ERP vendor: | SAP |
| • Consultant: | Plaut Consulting |

*B.2. News release/announcement*

HEADLINE: Daw Technologies Selects Oracle Over Its Competitors for Financial and Manufacturing Applications; Oracle's FastForward(SM) Approach Enables Rapid Implementation; Month-End Close Cut from Two Weeks to Two Days

DATELINE: SALT LAKE CITY, July 7, 1997, Monday

BODY: Oracle (Nasdaq: ORCL) today announced that Daw Technologies (Nasdaq: DAWK), a global provider of ultraclean environments that specializes in the design, manufacture and installation of cleanrooms to the semiconductor industry, expects to complete its six-month Enterprise Resource Planning (ERP) implementation of Oracle Applications(TM) in July. The rapid implementation has been made possible by Oracle Consulting Services'(SM) new FastForward(SM) approach, an offering designed to deliver fast time-to-benefit for mid-sized companies implementing Oracle Applications. The Oracle package, including Oracle Financials (R), Oracle (R) Manufacturing and Oracle (R) Projects application suites as well as Designer/2000(TM), Developer/2000(TM) and Discoverer(TM) tools, is expected to help Daw Technologies manage its rapid growth through improved data access, consistent data integrity, and more cost-effective systems for managing projects.

Data Gathered:

| | |
|---|---|
| • Client: | Daw Technologies |
| • Implementation window: | 6 months ended July 1997 |
| • Years of implementation: | Calendar year 1997 |
| • ERP vendor: | Oracle |
| • Consultant: | Oracle Consulting Services |

*B.3. News release/announcement*

HEADLINE: Nabi Goes Live with HP Rapid/3 Implementation OF R/3

DATELINE: Orlando, FL.

BODY: Aug. 25, 1997 — Hewlett-Packard Company today announced that Nabi, a leading biopharmaceutical company, has gone live with an HP Rapid/3 implementation of SAP's R/3. The fixed-price project, managed by HP's Professional Services Organization, was completed in only seven months.

The company urgently needed to integrate its business functions and replace existing systems as a result of its rapid growth. Nabi, one of the world's largest independent providers of human plasma products, required a new system that could deliver timely, accurate data and that could interface with its plasma-donor management system. In 1996, Nabi selected R/3 to meet its current and future needs and chose HP's Rapid/3 accelerated-implementation approach, which incorporates SAP's Accelerated SAP methodology to deliver benefits to the organization quickly. According to Nabi, the project would not have been as successful without HP's participation . . .

Data Gathered:

| | |
|---|---|
| • Client: | Nabi |
| • Implementation window: | 7 months ended August 1997 |
| • Years of implementation: | Calendar year 1997 |
| • ERP vendor: | SAP |
| • Consultant: | Hewlett-Packard's Professional Services Organization |

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