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An Examination of Lag Effects in Relationships between Information Technology Investment and Firm-Level Performance

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Abstract

We focus on two issues that have hindered understanding of the IT investment - firm performance relationship: the variety of firm performance measures used and the existence of a time-lag for performance effects. We develop theoretical arguments concerning the nature of different classes of performance measures and their abilities to capture the effects of IT investment initiatives as well as the nature of the lag effect for different types of IT investments. Our empirical findings generally confirm our theoretical arguments. Automate IT investments demonstrate the most evident impacts on firm performance as they were observed for three categories of firm performance: Production costs, profitability, and market valuation. Transform IT investments performance impacts are most evident with profitability. Secondly, our findings provide mixed evidence regarding the nature of the lag between the time of an IT investment and its influence on firm performance. Specifically, for accounting-based performance metrics, transform IT investments exhibit a longer time-lag than automate IT investments; for market-based performance metrics, the reverse was observed. Finally, it appears that informate IT investments may be the most challenging type of IT investment to link to firm performance.

Keywords: Business value of IT, firm performance, IT investment

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1. Introduction

While Information Technology (IT) investments account for a significant proportion of firms' capital investments (Jorgenson 2001), demonstrating how IT investments produce business value has proven to be a complex issue confronting academicians and practitioners. Prior to the mid-1990s, research was unable to detect a positive relationship between investment in IT and firm performance - a phenomenon generally referred to as the "productivity paradox" (e.g., Loveman 1994). However, studies that applied richer theoretical models to more robust data sets observed positive returns from IT investments (e.g., Brynjolfsson and Hitt 1996, Santhanam and Hartono 2003). Still, among others, two issues continue to impede efforts to understand the IT investment/firm performance relationship: inconsistent results across distinct firm performance metrics, and the existence and nature of lag effects.

First, it is well understood that IT investments are not interchangeable. Different categories of IT investments, e.g., automate, informate, and transform (Schein 1992), induce distinct performance effects through their differential impacts on organizational processes, product-markets and capabilities (Dehning, Richardson and Zmud 2003, Weill 1992). However, the majority of empirical studies that examine the business value of IT at a firm level have conceptualized and measured firms' IT investments in a singular manner (Dehning and Richardson 2002). It should not be surprising, then, that inconsistent results are observed across studies relying upon distinct firm performance metrics.

Second, it is also recognized that lag effects are likely to exist between instantiations of IT investments and observations of the firm performance impacts of these investments (Brynjolfsson and Hitt 1996, Dehning and Richardson 2002). Again, however, little empirical research has systematically addressed this issue, and the lag structures identified in the studies that have been conducted are quite diverse (e.g., Devaraj and Kohli 2000, Loveman 1994).

This study seeks to enhance our collective understanding of the business value of IT by addressing the following research question: *How do distinct types of IT investments differ in their effects and corresponding lag structures regarding dissimilar aspects of firm performance?* More specifically, the impacts of three categories of IT investments (automate, informate, and transform) on three distinct measures of firm performance (production costs, operating profit, and market performance) are assessed allowing for lag effects of one, two and three years.

2. IT Investments and Firm Performance Metrics

Previous research has taken different approaches to investigate IT investments and their impacts on firms' business performance. Investments in IT have been categorized into: 1) IT spending, i.e., amount of money spent on IT, 2) IT strategy, i.e., the nature of IT investments, and 3) IT management/capability, i.e., how IT assets are managed (Dehning and Richardson, 2002). In this study, we adopt the IT strategy approach and investigate IT investments as different types of IT applications/initiatives that comprise a firm's IT portfolio. Previous research studying IT strategy has utilized different typologies of IT initiatives, such as IT initiatives aimed to minimize costs, increase product quality, or drive economics of scale and/or growth (Oh and Pinsonneault 2007); or transactional, informative, and strategic IT initiatives (Weill 1992). Here, we follow the approach of Dehning et al. (2003) and adopt a widely used typology of IT initiatives in which IT initiatives serve three strategic roles within organizations (Schein 1992; Zuboff 1988),:

- Automate, i.e., replacing human labor by automating business processes.
- Informate (up or down), i.e., facilitating access to information by managers and employees.
- Transform, i.e., redefining business and industry practices, processes and relationships.

Different categories of IT investments have been found to induce firm-level performance effects (Anderson et al. 2006, Dehning et al. 2003, Weill 1992). Prior research has also argued that it is unlikely that distinct IT investments would produce similar influences on different business processes and overall firm performance measures (e.g., Dehning and Richardson 2002). Although such differences have been observed (e.g., Barua, Kriebel, and Mukhopadhyay 1995), previous research has not provided adequate theoretical explanations for these differences.

The notion of the balanced scorecard has made clear the recognition that different performance measures capture distinct aspects of firm performance (Kaplan and Norton 1992). If different types of IT investments are expected to influence firm performance in distinct ways, then it follows that different performance measures might reveal these distinct relationships. Previous research has investigated the impacts of IT investments on different aspects of firm performance. IT investments have been found to have significant impacts on business process efficiency such as inventory turnover (Barua et al. 1995). Numerour studies have investigated the impacts of IT investments on overall firm performance measures. Within this approach, research has utilized two types of performance measure: 1) Accounting performance measures, such as return on assets, return on equity, etc., and 2) Market performance measures, such as market valuation of common equity, Tobin's q, or abnormal stock returns (Dehning and Richardson, 2002). Adopting the overall performance approach, we look at three types of overall firm performance, aiming to provide a better explanation for the impacts of different types of IT initiatives on different aspects of overall performance, as well as their lag structures. The chosen set of performance measures gives us a broad picture of the potential impacts of IT investment initiatives on firm-level performance as they reflect three distinct aspects of firm performance.

- *Production Costs* measures reflecting direct inputs required to produce a given output. Production costs include costs of input material and direct labor costs required for the transformation of inputs into outputs. These measures typically focus on cost structures and asset efficiencies, and reflect the efficiencies of the production process.
- *Operating profit* measures reflecting profits gained from ongoing business operations alone, excluding financial and accounting tactics as well as extraordinary events. These measures typically focus on the profit margins, i.e., the difference between operating revenues and costs, and are enhanced by increasing revenues, decreasing costs, or both.
- *Market performance* measures reflecting market's valuation of a firm's future performance. Different from the first two measures, which are accounting-based and thus historical in nature, market valuation measures are forward looking. Further, market valuations account for all of an organization's business activities, incorporating sources of revenues and costs beyond those directly associated with operations, and thus also capture intangible benefits of IT investments (Bharadwaj, Bharadwaj, and Konsynski, 1999).

It is important to note that IT investments are not expected to affect performance measures in a 1:1 manner; instead, these relations tend to be both N:1 (i.e., multiple and distinct IT investments occurring within a window of time will directly and/or indirectly affect a selected measure) and 1:N (i.e., a specific IT investment will directly or indirectly affect multiple measures) (Dehning, Richardson, Smith and Zmud, 2007). Recognizing such equifinality in the relationship between IT investment and measures of firm performance, the hypotheses are presented in a three-step manner. First, for each level of performance measurement, arguments are developed regarding the likelihood that a specific type of IT investment would engender a significant effect. Second, again for each level of performance, arguments are developed for the relative effects of the three types of IT investment. The final hypothesis posits expected lag structures for the three types of IT investment initiatives.

2.1 Specific IT Investment Effects

Utilizing the production function view, research has argued for IT investment' potential to help firms reduce costs associated with business activities (Barua et al. 1995; Brynjolfsson and Hitt 1996). IT investment initiatives most likely to reduce a firm's production costs are those that directly reduce the inputs and resources required to produce a given level of outputs. By simplifying, accelerating and coalescing repetitive business processes, automate IT investment initiatives focus directly on enhancing work processes via increased throughput, labor savings and cost reductions (Mooney et al. 1996) and, as a result, are expected to lead to reductions in costs that are directly linked to the production of outputs. While certain informate (enhanced resource allocation decisions) and transform (reduced cost structures via radically changed business practices) IT investment initiatives would be expected to also reduce these production costs, it is expected that the majority of such investments focus on producing substantially higher revenues (e.g., investments in business intelligence applications) or transitioning to higher-margin product-market regimes (e.g., platform investments enabling mass customization). We therefore expect automate IT investment initiatives to be particularly prominent in reducing firms' direct costs:

Hypothesis 1: Automate IT investment initiatives are expected to reduce a firm's production costs.

Profitability measures are improved by enhancing margins, i.e., by increasing revenues, decreasing costs or, ideally, both. All three categories of IT investment initiatives are likely to contribute to firms' profitability improvement: automate through the production costs reduction as discussed above; and, informate and transform via pathways affecting revenue structures and cost structures. Informate IT investment initiatives provide enhanced (accuracy, timeliness, completeness, etc.) information regarding internal and external business events and activities, empowering a firm's employees as well as customers, suppliers or partner firms to enhance decision and coordination processes such that product/service targeting and quality, responsiveness, and resource utilization are all improved (Mooney et al. 1996). Transform IT initiatives reposition firms within new, higher-margin product-market regimes (Dehning et al. 2003) by operating within less competitive product-markets, with dramatically lower cost structures, or both. Therefore, we believe all three types of IT initiatives will improve firms' profitability measures:

Hypothesis 2a: Automate IT investment initiatives are expected to improve a firm's profitability outcomes.

Hypothesis 2b: Informate IT investment initiatives are expected to improve a firm's profitability outcomes.

Hypothesis 2c: Transform IT investment initiatives are expected to improve a firm's profitability outcomes.

Market performance measures are capable of capturing market's valuation of a firm's future performance. These measures reflect the market's assessment of the expected return to shareholders generated from all of a firm's activities, operational and non-operational. Thus, these measures capture business activities that contribute to a firm's long-run performance as well as intangible values that might not be reflected in accounting measures. Previous research has shown that capital markets respond to information about IT investments, resulting in positive impacts of IT investments on firms' market valuation (Dehning and Richardson 2002). Thus, market performance measures can be used to capture the contributions of IT investment initiatives to operational and non-operational aspects of firm activities as well as a broad spectrum of intangible assets (Bharadwaj et al. 1999).

While automate IT investment initiatives might not increase a firm's sustainable competitive advantage because they can easily be copied (Dehning et al. 2003), many such investments have become competitive necessities and thus do contribute to long-run firm performance. By providing enhanced information that supports decision making and coordination, informate IT investments can contribute to higher product and service quality, improved coordination with suppliers, superior customer relationships, and smoother flow of information and material (Bharadwaj et al. 1999; Mooney et al. 1996; Dehing et al. 2003). While some of these effects are likely to be captured as increased revenues, others are intangible in nature and thus difficult to be captured capture via accounting-based performance measures. However, such intangibles are expected to contribute to firms' earnings growth prospects and thus are likely to be reflected in market performance measures (Bharadwaj et al. 1999). Transform IT investment initiatives, which aim to bring about radical changes to business models so as to disrupt existent industry practices in significant ways, have been observed to help firms move into new, attractive product-market regimes, creating attractive growth prospects (Dehning et al. 2003). In addition, transform IT investment initiatives are difficult for competitors to imitate (Dehning et al. 2003), thus are likely to create sustainable competitive advantage when successfully implemented. Hence:

Hypothesis 3a: Automate IT investment initiatives are expected to improve a firm's market value.

Hypothesis 3b: Informate IT investment initiatives are expected to improve a firm's market value.

Hypothesis 3c: Transform IT investment initiatives are expected to improve a firm's market value.

2.2 Relative IT Investment Effects

While automate IT investments, with their focus on improving existing work processes, are expected to directly impact production costs, informate and transform IT investments may or may not reduce costs per se. Informate IT initiatives focus on improving information flows which may result in costs reduction but may as well be targeted at improving revenue flows through mechanisms such as selecting superior product mixes, improvements in customer service, etc. Although transform IT investments could focus on reducing costs, their aim is typically to alter traditional ways of conducting business by disrupting existing markets or allowing a firm to define or otherwise enter a new market. Such actions do not necessarily reduce cost structures. In fact, one could very well imagine that operating costs might initially increase as a firm moves away from existing business practices. Hence, of the three types of IT initiatives, it is the influence of automate IT investment initiatives that is expected to be most associated with costs reduction.

Hypothesis 4: *Automate IT investment initiatives are expected to have a greater influence on a firm's production costs reduction than are informate or transform IT investment initiatives.*

IT investments most likely to improve profitability measures are those that affect *both* the numerator (revenues) and denominator (costs) of profitability metrics. As argued, automate IT investment initiatives' impacts are focused on reducing production costs, which are directly linked to the production process. Meanwhile, besides their influence on helping firms increase revenue as argued earlier, informate and transform IT investments initiatives are also argued to have potential significant impacts on direct costs, i.e., enhanced resource allocation decisions, as well as on other cost factors not directly linked to the production process, i.e., costs factors proportionally allocated to all units of outputs, such as salaries, rent, advertising expenses, etc. (Mooney et al. 1996), or linked to monitoring and control activities such as agency costs, costs of inventory outages, wastage, mismanagement and other costs related to the complexity of the organization (Mitra and Chaya 1996).

Informate IT investment initiatives can also provide management and employees with information regarding internal and external business events and activities. With an enhanced information environment, management can better understand the firms' business processes, track costs, identify and eliminate unprofitable lines of business, track performance of subordinates, and otherwise grow the company without losing control. These improvements would lead to better decisions with regard to utilizing resources and hence reduce direct, overhead and agency costs. While the effects of transform IT initiatives ultimately aim at increasing revenue and growth (Weill 1992, Mooney et al. 1996), innovated business processes can also lead to better responsiveness, reduced cycle times and overhead costs. In addition, resultant changes in organizational structure tend to produce business platforms characteristic of much leaner organizations, helping firms reduce agency costs and monitoring costs per product unit. Therefore, informate and transform IT investment initiatives can possess significant impacts on both revenues and costs. Thus, it is arguable that informate and transform IT initiatives have broader impacts on profitability than automate IT initiatives. Hence we propose:

Hypothesis 5: *Informate and transform IT investment initiatives are expected to have a greater influence on a firm's profitability outcomes than are automate IT investment initiatives.*

IT investment initiatives expected to have greater impacts on a firm's long-run performance and broader impacts on the firm's business activities are more likely to have stronger impacts on the firm's market performance metrics. The impacts of automate and informate IT investment initiatives tend to be short-lived given that they are more easily copied by competitors (Dehning et al. 2003). Meanwhile, transform IT investment initiatives prove to have greater sustainable competitive advantage since they bring about radical changes to business models so as to disrupt existent industry practices, making them high-risk, high-return investments difficult to be copied by competitors (Dehning et al. 2003). Additionally, transform IT investment initiatives also produce broad, systemic affects (such that many facets of a firm are simultaneously impacted) on firms' business activities, thus are broader in their impacts than that of either automate or informate IT investment initiatives. Given these arguments, we would expect transform IT investment initiatives to have stronger impacts on firms' market performance:

Hypothesis 6: *Transform IT investment initiatives are expected to have a greater influence on a firm's market performance than are informate or automate IT investment initiatives.*

2.3 Lag Structure Effects

Finally, another important issue in understanding the relationship between IT investment initiatives and firm performance concerns the timing as to when performance impacts of IT investment initiatives are felt. The few studies examining the issue exhibit inconsistencies in terms of observed lag periods. For example, Loveman (1994) found positive significant impacts of IT capital on performance with a two-year lag, while Devaraj and Kohli (2000) observed a three-month lag for IT capital. One explanation for these inconsistencies is that these previous studies did not account for differences in the nature of IT investments.

There are three primary explanations for why delays are likely to arise with the performance impacts from IT investment initiatives: learning effects, structural effects, and complementary effects. First, it often takes time for a firm's employees to learn how to exploit installed IT (Barua and Mukhopadhyay 2000). Second, firms must often adjust their business processes as well as their control and incentive structures to accommodate the adoption of new IT (Brynjolfsson and Hitt 1998); such adjustment takes time to take effect beyond that required to install the new technology. Finally, to fully leverage investments in IT assets and IT-enabled capabilities, investments in complementary technologies and capabilities are often required (Tanriverdi and Ruefli 2004); again, it takes time to introduce such complementarities.

Further, it is anticipated that the three types of IT investments (automate, informate and transform) will exhibit varying lag structures due to their differential requirements for learning, structuring, and complementarities. Most obvious is an expectation that informate IT investments will experience greater lag effects than automate IT investments given the substantial needs to train employees in new decision and coordination processes and, often, the needs for structural and cultural changes to create climate within which employees are motivated to apply these new processes (e.g., Carte, Schwarzkoph, Shaft and Zmud 2005). Similarly, as transform IT investments require new or radically-changed business processes and organizational capabilities as well as the provisioning of complementary assets (Krough, El Sawy and Gray 2006), we expect transform IT investments to exhibit a longer lag structure than automate IT investments. We cannot theoretically argue for differences regarding the lag structures of informate and transform IT investments. This leads to our final hypothesis:

Hypothesis 7: *The performance impacts associated with* ***automate IT*** *investment initiatives are expected to exhibit shorter lag structures than are the performance impacts associated with* ***informate*** *and* ***transform*** *IT investment initiatives.*

3. Research Methodology

Figure 1 depicts our research model. The independent variables are automate, informate and transform IT investment initiatives, with multiple lag structures. The dependent variable is firm performance, captured as production costs, operating profit and market performance metrics. The rationale for and the manner by which these variables and the study's control variables are operationalized are next described.

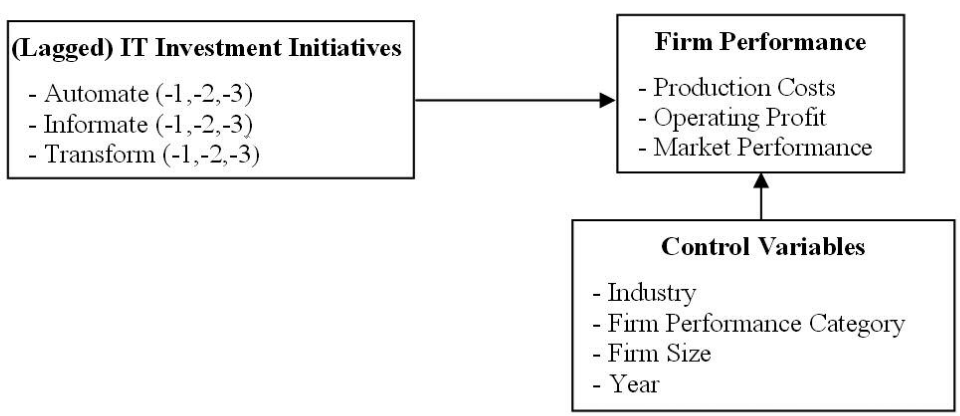

Figure 1. The Research Model

3.1. IT Investment Initiatives

To examine our hypotheses, we require data on the nature of firms' IT investment initiatives. However, such data is not readily available via extant data archives, a major barrier for scholars intent on understanding the IT investment/ firm performance relationship. Therefore, consistent with approaches taken in prior research (e.g., Dehning et al. 2003, Jarvenpaa and Ives 1990), IT-focused strategic signals are used as indicators of IT investment initiatives. Strategic signaling refers to firms' communications of actions or intended actions to various constituencies (Heil and Robertson 1991); IT strategic signaling refers specifically to communications regarding firms' IT-related initiatives and activities.

With rare exceptions, e.g., the research reported by Jarvenpaa and Ives (1990, 1991), prior research examining firms' IT strategic signaling behaviors has used press releases as the primary data source. Here, we follow Jarvenpaa and Ives and use firms' annual reports as the primary data source for four reasons. First, strategic signals in press releases may not be realized (due to bluffing or to postponed or failed implementations) or realized only in part. In certain cases, firms' strategic signals are more symbolic than substantive (Westphal and Zajac 2001). Statements in firms' annual reports, on the other hand, tend to focus on communicating what has occurred (Salancik and Meindl 1984). Second, these accounts of what has occurred are argued to be relatively accurate and objective (e.g., Bettman and Weitz 1983), given the scrutiny such documents received from various constituencies, including the U.S. Securities and Exchange Commission (SEC). Third, these accounts of what has occurred are argued to be comparable across firms (Bettman and Weitz 1983) and stable over the short and intermediate term within a firm (Adams 1997, Lev 1992). Fourth, organizations are prone to incorporate technical issues (e.g., information technology) into their annual reports, as technical issues have been observed to be particularly effective in explaining or legitimizing past actions (Arndt and Bigelow 2000). Thus, firms' reports of IT-related initiatives and associated accomplishments via annual reports promise to provide comparable, stable and accurate reports of their IT investment activity.

Since collecting and coding IT investments data from firms' annual reports is a laborious process, we used a theoretical sampling approach (Denzin 1989) in order to help reduce the sample size but still guarantee the accuracy of our empirical analysis. Specifically, we required a sample that (1) was diverse in both investment intensity and range of IT activities reported by selecting firms from industries where IT dominantly plays automate, informate, and transform strategic roles, and (2) not biased toward high performing firms by selecting both high and low performing firms from each individual industry investigated. This second criterion is especially salient, given the causality concerns frequently raised regarding the relationship between IT investment and firm performance, i.e., does IT investment lead to higher firm performance or does higher firm performance provide the surplus capital required for IT investment?

Industries can be classified as being characterized by a dominant industry IT strategic role, i.e., where competitive actions tend to be enabled via by automate, informate or transform IT investments (Chatterjee et al. 2001). By including firms from industries that are representative of each industry IT strategic role, it is more likely that a full range of IT investment initiatives will be observed. In sampling firms within an industry, it was desired to be conservative with regard to causality arguments. Thus, an equal number of an industry's highest performers (those firms most likely to have available capital for investment) and lower performers (those firms least likely to have available capital for investment) were selected. Hence, the study's sample consisted of the highest and lowest performing firms from three industries, with each industry characterized by a distinct industry IT strategic role.

We relied upon the Chatterjee et al. (2001) classification structure to identify candidate industries. The three industries selected were: *primary metal manufacturing* (METALS: NAICS code 331), *specialty retailing* (RETAIL: NAICS codes 442 {Furniture and Home Furnishing Stores}, 448 {Clothing and Clothing Accessories Stores} and 4511 {Sporting Goods, Hobby, and Musical Instruments}), and *financial services* (FINANCE: NAICS code 523), which respectively have industry IT strategic roles of automate, informate, and transform. To select the high and low performers in each industry, five years of data (1996-2000) were used to create an industry-specific composite performance indicator based on industry specific factor analyses of the performance ratios recommended by Standard & Poor's. Based on the resulting factor scores, firms were then ranked within their respective industry with the five highest-performing and five lowest-performing firms selected for inclusion The final sample included 30 companies, 10 from each of industry.

For each firm, IT investment initiatives were collected from these firms' annual reports for 1996-2000. Annual report contents considered during the coding process included the CEO's letter to shareholders and other materials prior to management's discussion and analysis of financial data. Management's discussion and analysis of financial data were excluded because the IT issues discussed therein appeared to be 'boiler plate,' i.e., did not change much (if at all) from year to year. Also, statements on year 2000 preparedness were not coded because year 2000 preparedness was a one-time issue affecting all firms and was not considered indicative of IT-related activities unique to a firm; including signals regarding year 2000 preparedness initiatives would have created a severe time-bias in the data.

To surface and categorize firms' IT investment initiatives, four coders independently examined the contents of each firm's annual reports. Coding was conducted at the paragraph-level as this seemed to be the level of articulation that best placed IT investment initiatives in business context (i.e., the business objectives being sought) such that the business intent associated with the investment initiative could be ascertained. For any paragraph that discussed one or more IT initiatives, each coder assigned a code to indicate the nature of the initiative (i.e., automate, informate or transform) following the coding rules.

An initial set of coding rules were developed from a pilot test using two firms not included in the sample. The coders then examined each firm's annual reports in sequence. Once the coding for a firm was complete, the coders met to assess agreement regarding the codes assigned for that firm, to resolve disagreements, and to refine the coding rules (being careful to insure that new rules did not create inconsistencies with previous code assignments). This approach maintained intra- and inter-coder consistency throughout the coding process, resulting in counts of the number of signals of each type of IT investment initiative (automate, informate, or transform) for each firm, for each year. We assessed reliabilities for each coders compared to the final agreed-upon code via Cohen's (1960) Kappa; "substantial" (0.61-0.80) or "almost perfect" (0.81-1.0) levels of agreement (Landis and Koch 1977) were observed for each coder. The coding rules and coding examples are included in the appendix.

3.2 Firm Performance Metrics

Accounting ratios were employed to measure production costs and operating profitability: Cost of goods sold divided by sales for production costs, and operating profit (operating income before depreciation / sales) for profitability. Market value divided by book value ([Price-Calendar Year Close * Common shares Outstanding]/ Common equity) was used to measure market performance.

Cost of goods sold indicates the costs of production, or costs of inputs that are transformed into end products output, such as direct labor, machinery, raw materials, warehousing, purchased merchandises, etc. Costs of goods sold to sales has been used as an indicator of cost-based performance (Bharadwaj 2000). Operating profit is often used to measure the profitability of firms' operational activities (Kaplan 1989), as it indicates the added value being produced from ongoing operations and excludes revenues from non-operating activities (e.g., financial leverage). Market value has been used by previous research to capture market performance of firms as influenced by IT investments (e.g. Brynjolfsson, Hitt, and Yang, 2002).

Signaling data was collected for the five years 1996-2000. Since it was unknown when a coded IT investment initiative occurred during the year being reported, a zero-lag effect was not examined. Accordingly, the hypotheses were assessed for one-, two- and three-year lag structures, with a one-year lag being the most immediate impact. To fully utilize the signals data set simultaneously considering all three lags, performance metrics were extracted from the COMPUSTAT database for 1999 - 2001.

For financial services firms, Selling, General, and Administrative (SGA) expenses are included in Cost of Goods Sold (COGS) in the COMPUSTAT database, requiring the manual removal of SGA expenses from the reported COGS using data from the firms' income statements. For brokerage firms, the entries 'brokerage commissions' and 'clearance fees' were used for COGS; for mortgage firms, the entry 'mortgage insurance and other' was used for COGS. With this COGS adjustment for financial services firms, the three performance metrics are robust across the three industries comprising the study's sample. Table 1 provides descriptive statistics for the IT investment signals and the firm performance metrics. Signal data were reported as the number of signals coded for in the annual reports.

3.3. Control Variables

We control for industry and firm performance (treating each as a categorical variable) to minimize the risk that the sample selection process introduces systematic biases into the results. To control for scale effects, firm size is captured by a log transformation of the number of employees of each firm (Kimberly 1976). Finally, to control for general economic trends, year was included as a categorical variable.

Table 1. Descriptive Statistics

Year		Automate (# of signals)	Informate (# of signals)	Transform (# of signals)	Production Costs (COGS/S)	Operating Profit (OI/S)	Market Performance (MV/BV)
1996	Mean	2.10	0.80	0.17	N/A	N/A	N/A
	(SD)	(4.25)	(1.42)	(0.59)	N/A	N/A	N/A
1997	Mean	2.10	0.80	0.23	N/A	N/A	N/A
	(SD)	(3.93)	(1.35)	(0.77)	N/A	N/A	N/A
1998	Mean	3.60	0.77	0.30	N/A	N/A	N/A
	(SD)	(7.19)	(1.43)	(0.92)	N/A	N/A	N/A
1999	Mean	4.63	1.20	0.47	0.49	0.17	3.55
	(SD)	(7.39)	(2.22)	(1.07)	(0.37)	(0.22)	(5.04)
2000	Mean	5.40	1.00	1.03	0.50	0.17	2.46
	(SD)	(12.04)	(1.76)	(2.80)	(0.37)	(0.21)	(2.98)
2001	Mean	N/A	N/A	N/A	0.51	0.12	2.21
	(SD)	N/A	N/A	N/A	(0.38)	(0.22)	(2.55)

3.4. Analysis Strategy

We analyzed the data using SAS's PROC MIXED routine as it allows the estimation model to include categorical control variables (year, industry, performance category), continuous control variables (firm size), and continuous independent variables (IT investment signals). In addition, PROC MIXED is appropriate for longitudinal analysis, where repeated measurements, i.e., IT investment signals and firm performance metrics, are taken over time[1].

While PROC MIXED assumes that the dependent variable is normally distributed, the performance metrics (from only industry top and bottom performers) are not normally distributed. To address this, we transformed the performance metrics into ranks (Arkritas and Brunner 1997). Each performance measure for a firm was transformed into a rank score, where the ranking was relative to the same performance measure of all firms in the data set across the three years of performance data (1999-2001).

To examine hypotheses 1, 2, and 3 each type of IT investment initiative was analyzed separately to ascertain the affects, including lag structure, of that specific type of initiative. Here, for each performance metric, two models are provided: a model containing only the control variables, and then a second model with both control variables and three lag variables for the IT investment initiative type. Then, to assess the relative effects of the three types of IT investment initiatives (hypotheses 4, 5, and 6), a similar modeling strategy was applied with all three types of IT investment initiatives included in the second model. In all cases, the addition of the IT investment initiatives resulted in a statistically significant increase in model fit. Hypothesis 7 is assessed through examination of the analyses conducted to investigate the other hypotheses.

4. Results

Hypotheses 1, 2a, and 3a which argue respectively that automate IT investment initiatives would significantly impact production costs, operating profitability, and market performance are supported. As seen from Table 2, automate IT signals impact direct costs (one-year lag, $p=0.04$)[2], profitability (one-year lag, $p<0.01$), and market performance (two-year lag, $p<0.001$).

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[1] PROC MIXED, like PROC GLM, fits a linear model to the data. While GLM also facilitates the inclusion of both categorical and continuous variables, it does not support random effects of independent variables as repeated measures. PROC MIXED also allows one to specify a covariance structure. As our independent variables are equally-spaced time series data, we specified the First Order Autoregressive Structure (AR(1)) for all analyses.

[2] To investigate if this result could be attributed to the recalculations of the COGS/S measure for firms in the financial services industry, the analysis was rerun without these financial services firms. The results were consistent. We performed this re-analysis for informate and transform IT investment initiatives with similar outcomes.

Table 2. Analysis Results – Automate Impact[3]

			Production Costs (COGS/S)		Operating Profit (OI/S)		Market Performance (MV/BV)	
Size		F	0.07	1.44	5.89	0.32	13.62	6.58
		p	0.79	0.24	0.02	0.58	<0.001	0.01
Industry		F	285.88	144.86	17.09	3.38	4.50	1.22
		p	<.0001	<.0001	<.0001	0.05	0.02	0.31
Performance Category		F	42.17	42.81	63.68	83.99	22.23	24.09
		p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Year		F	4.45	5.01	5.24	7.89	3.28	5.38
		p	0.02	0.01	<0.01	0.001	0.04	<0.01
-2 LL for controls			516.40		626.60		674.90	
Automate	1-year lag	β		**-4.50**		**14.08**		5.26
		F		**4.69**		**9.86**		1.06
		p		**0.04**		**<0.01**		0.31
	2-year lag	β		-1.97		***6.71***		**15.83**
		F		1.24		***3.29***		**13.98**
		p		0.27		***0.08***		**<0.001**
	3-year lag	β		1.08		1.03		-3.34
		F		0.39		0.08		0.66
		p		0.53		0.78		0.42
-2 LL full model				502.60		599.00		646.00
Δ -2 LL				14.60		27.60		28.90
Δ -2 LL p value[4]				**<.005**		**<.001**		**<.001**

Hypotheses 2b and 3b which posit that informate IT investment initiatives would significantly impact operating profit and market performance were not supported (see Table 3). In fact, while an impact was observed for market performance (three-year lag, $p<0.01$), it was negative. It is noteworthy, however, that a positive effect was observed regarding profitability near conventional levels of significance (two-year lag, $p=0.08$).

Hypotheses 2c and 3c which argue that transform IT investment initiatives would significantly impact operating profit and market performance were supported. As seen from Table 4, the impact of transform IT investment initiatives on profitability was observed (one-year lag, $p<0.01$; two-year lag, $p=0.02$) as was that regarding market performance (one-year lag, $p=0.01$).

To examine Hypotheses 4, 5, and 6, the effects of automate, informate and transform IT investment initiatives were simultaneously considered. As shown in Table 5, automate IT investment initiatives exerted a dominant influence (one-year lag, $p=0.02$) on production costs. Therefore, Hypothesis 4 is supported. However, neither Hypothesis 5 nor Hypothesis 6 was supported. Regarding Hypothesis 5, which posited that the influence of informate and transform IT investment initiatives on profitability would be greater than that observed for automate IT investment initiatives, impacts were observed for both automate IT investment initiatives (one-year lag, $p=0.02$) and transform IT investment initiatives (two-year lag, $p=0.04$) but not for informate IT investment initiatives. Regarding Hypothesis 6, which posited the influence of transform IT investment initiatives on market performance would be greater than that observed for automate or informate IT investment initiative, positive impacts were observed for automate (one-year lag, $p=0.04$) and transform (one-year lag, $p=0.05$) but a negative impact was observed for informate (three-year lag, $p=0.02$; two-year lag, $p=0.08$).

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[3] β values are reported for signal variables to indicate directionality.

[4] Δ -2 LL: is the difference between the "minus 2 times REML Log-likelihood" of the analysis model with only control variables and that of the analysis model with control and independent variables. If p value of Δ -2 LL is significant, the addition of independent variables to the analysis model with only control variables significantly increases the overall fit of the analysis model.

Table 3. Analysis Results – Informate Impact								
			Production Costs (COGS/S)		**Operating Profit (OI/S)**		**Market Performance (MV/BV)**	
Size		F	0.07	0.05	5.89	2.28	13.62	16.76
		p	0.79	0.83	0.02	0.14	<0.001	<0.001
Industry		F	285.88	247.93	17.09	14.26	4.50	5.25
		p	<.0001	<.0001	<.0001	<.0001	0.02	0.01
Performance Category		F	42.17	39.10	63.68	62.57	22.23	15.39
		p	<.0001	<.0001	<.0001	<.0001	<.0001	<0.001
Year		F	4.45	4.32	5.24	6.58	3.28	3.56
		p	0.02	0.02	<0.01	<0.01	0.04	0.04
-2 LL for controls			516.40		626.60		674.90	
Informate	1-year lag	β		-0.81		7.69		-2.54
		F		0.10		1.74		0.14
		p		0.76		0.19		0.71
	2-year lag	β		0.06		***9.40***		-4.02
		F		0.00		***3.28***		0.44
		p		0.98		***0.08***		0.51
	3-year lag	β		1.28		-0.36		**-19.07**
		F		0.26		0.01		**10.22**
		p		0.61		0.94		**<0.01**
-2 LL full model				505.00		606.30		650.30
Δ -2 LL				11.40		20.30		24.60
Δ -2 LL p value				**<.005**		**<.001**		**<.001**

Hypothesis 7 posited that automate IT investment initiatives would be observed to have a more immediate impact than informate and transform IT investment initiatives. We observed differing results regarding the accounting-based performance metrics (production costs and operating profit) and the market-based performance metric (market performance).

For the accounting-based metrics, Hypothesis 7 did receive support:

- The significant impacts for automate IT investment initiatives were observed to be characterized by a one-year lag, the most immediate effect;
- The only near-significant impacts for informate IT investment initiatives (observed for operating profit) was characterized by a two-year lag;
- While significant one-year lag effects were observed for transform IT investment initiatives when they were considered alone (Table 4), the significant impact observed when considered along with automate and informate IT investment initiatives (Table 5, operating profit) was characterized by a two-year lag.

However, quite different results were observed with the market-based metric. Here, the transform IT investment initiatives were characterized as having a one-year lag, the automate IT investment initiatives with a two-year lag, and the informate IT investment initiatives with *a negative* three-year lag. It appears that the market immediately accounts for transform IT investment initiatives, is somewhat delayed in its reaction to automate IT investments but seems to overtly question the long-term value of informate IT investments.

Table 4. Analysis Results – Transform Impact								
			Production Costs (COGS/S)		**Operating Profit (OI/S)**		**Market Performance (MV/BV)**	
Size		F	0.07	0.07	5.89	0.25	13.62	8.14
		p	0.79	0.79	0.02	0.61	<0.001	<0.01
Industry		F	285.88	252.64	17.09	6.20	4.50	3.94
		p	<.0001	<.0001	<.0001	<0.01	0.02	0.03
Performance Category		F	42.17	39.23	63.68	67.07	22.23	29.75
		p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Year		F	4.45	4.01	5.24	8.25	3.28	5.16
		p	0.02	0.02	<0.01	<0.001	0.04	0.009
-2 LL for controls			516.40		626.60		674.90	
Transform	1-year lag	β		-0.05		**21.52**		**22.41**
		F		0.00		**7.93**		**7.12**
		p		0.98		**<0.01**		**0.01**
	2-year lag	β		-0.65		**16.59**		3.75
		F		0.04		**5.37**		0.20
		p		0.84		**0.02**		0.66
	3-year lag	β		0.15		9.25		-6.47
		F		0.00		1.18		0.43
		p		0.97		0.28		0.52
-2 LL full model				504.40		598.50		648.60
Δ -2 LL				12.00		28.10		26.30
Δ -2 LL p value				**<.005**		**<.001**		**<.001**

5. Discussion and Future Research Directions

The objectives of this study were to investigate inconsistencies regarding two issues central to the relationship between IT investment and firm performance: inconsistencies across different firm performance metrics and the nature of observed lag structures with regard to the impacts of different types of IT investment initiative. The study's results indicate that progress was achieved regarding both of these objectives. The following sections discuss the most prominent findings from the studies, some inconsistencies observed in our study, and future research that would likely extend our understanding of how IT investment initiatives contribute to firm performance.

The most prominent finding is the dominating effect of automate IT investment initiatives: IT signals regarding automate IT initiatives were found to significantly influence all performance metrics (production costs, operating profit and market performance) in expected directions. Of the three types of IT investment initiatives, automate IT investment initiatives are generally well-understood by implementing firms, are characterized with rather direct relationship to value chain activities (Mooney et al. 1996, Weill 1992), and require relatively fewer complementary investments to produce value-added benefits. As a consequence, they pose a lesser risk of failure than informate and transform IT investments and their benefits are more easily recognized and understood by the market.

Another important finding was that automate IT investment initiatives displaced the immediate impacts of transform IT initiatives on operating profit. Most likely, this occurred because transform IT investment initiatives are considerably riskier than are automate IT initiatives, with this risk reflecting the heightened uncertainty of new product-market regimes and the complexities associated with implementing any complementary investment initiatives associated with the new business models (Barua and Mukhopadhyay 2000, Tanriverdi and Ruefli 2004, Weill 1992).

Transform IT initiatives were also found to significantly influence two performance metrics (operating profit and market performance) in expected directions. While Weill's (1992) study found negative impacts of strategic IT investment on firms' return on assets, here transform IT investment initiatives were observed to have positive impacts on performance. There are a number of explanations for these differing outcomes: the organizational learning regarding IT that has occurred since 1992, improved intra- and inter-organizational system integration capabilities, more robust IT infrastructures, more complementary investments in-place, more receptive and more facilitative industry ecosystems, and the tight research design of the current study.

Table 5. Analysis Results – Automate, Informate and Transform IT Signals

			Production Costs (COGS/S)		Operating Profit (OI/S)		Market Performance (MV/BV)	
Size (Number of employees)		F	0.07	0.57	5.89	0.72	13.62	9.79
		p	0.79	0.45	0.02	0.40	<0.001	<0.01
Industry		F	285.88	129.05	17.09	1.26	4.50	1.64
		p	<.0001	<.0001	<.0001	0.30	0.02	0.21
Performance Category		F	42.17	43.09	63.68	86.82	22.23	22.06
		p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Year		F	4.45	4.12	5.24	9.42	3.28	6.29
		p	0.02	0.02	0.0083	<.001	0.04	<0.01
-2 LL for controls			516.40		626.60		674.90	
Automate	1-year lag	β		**-5.91**		**11.15**		3.60
		F		**5.98**		**6.11**		0.55
		p		**0.02**		**0.02**		0.46
	2-year lag	β		-2.88		3.51		**10.87**
		F		1.96		0.77		**6.35**
		p		0.17		0.39		**0.04**
	3-year lag	β		1.13		-1.16		0.24
		F		0.30		0.07		0.00
		p		0.59		0.80		0.96
Informate	1-year lag	β		0.92		5.95		-4.84
		F		0.11		1.12		0.57
		p		0.74		0.30		0.46
	2-year lag	β		2.34		5.09		***-10.40***
		F		0.72		0.93		***3.18***
		P		0.40		0.34		***0.08***
	3-year lag	β		0.04		1.47		**-15.92**
		F		0.00		0.06		**5.85**
		p		0.98		0.81		**0.02**
Transform	1-year lag	B		2.32		11.94		**17.44**
		F		0.68		2.10		**3.97**
		p		0.41		0.15		**0.05**
	2-year lag	β		1.31		**15.39**		6.25
		F		0.16		**4.28**		0.59
		p		0.69		**0.04**		0.45
	3-year lag	β		0.22		5.95		-10.17
		F		0.00		0.49		1.07
		p		0.95		0.49		0.31
-2 LL full model				475.50		557.90		599.30
Δ -2 LL				40.40		68.70		75.60
Δ -2 LL p value				**<.001**		**<.001**		**<.001**

It is also important to note that our results suggest that the inconsistencies surfaced in prior research regarding lag structures may very well be explained by recognizing that different types of IT investment initiatives require different time periods in order for their benefits to be detected. As posited, the influence of automate IT investment initiatives was observed more immediately than those of informate and transform IT initiatives, but only for the accounting-based performance metrics. With the market-based performance metrics, transform IT investment initiatives were characterized by an immediate effect while automate IT investment initiatives had a two-year lag. There are a number of possible explanations: automate initiatives may form the foundation for subsequent transform initiatives; those automate initiatives whose benefits are competitively sustainable are valued by the market, etc. However, these results only begin to explore and unravel this important and complex set of relationships.

A compelling finding was the lack of effects regarding informate IT investment initiatives on the accounting-based performance metrics. Two explanations are conjectured to explain such an outcome. First, of the three categories of IT investment initiatives, informate initiatives are likely to require the most extensive array of complementary investments (e.g., decision and process redesign, organizational development, human resource development, structural realignment, etc.) in order for expected benefits to be realized (Barua and Mukhopadhyay 2000). Informate IT initiatives provide individuals with the capability to access and use significantly enhanced data assets and associated analysis tools. Such initiatives by themselves, however, neither account for the need to train or motivate individuals to make use of these enhanced information environments nor insure that these individuals have the authority to fully implement the decisions or actions subsequently taken. Second, compared to automate and transform IT investment initiatives, informate IT initiatives are characterized by the least direct pathway to performance outcomes. Not only will the quality of decisions or actions taken vary considerably across individuals operating within a given information environment, but numerous other variables and events invariably intervene. And, as discussed in arguing for hypothesis 4, many of the potential impacts of informate IT investment initiatives are intangible in nature and, hence, are likely to be difficult to be fully embodied via accounting-based performance metrics.

We were admittedly quite surprised (and a bit befuddled) by the *negative* effects observed for informate IT investment initiatives and the market performance metric. However, a closer examination of our data may yield a possible explanation for these results. As observed with these results and from our data, companies that engaged in a relatively greater amount of informate IT investments tended to be characterized by decreasing market values over the study's timeframe. Apparently, informate IT investment initiatives (market and business intelligence, introducing new ways to communicate with and support sales teams and customers, etc.) are particularly appealing to companies experiencing performance declines. And, at least from an installation perspective, informate IT investments can often be introduced fairly quickly and for incremental costs. However, of the three categories of IT investment initiatives, informate initiatives are likely to require the most extensive array of complementary investments (e.g., decision and process redesign, organizational development, human resource development, structural realignment, etc.) in order for expected benefits to be realized (Barua and Mukhopadhyay 2000). Informate IT initiatives provide individuals with the capability to access and use significantly enhanced data assets and associated analysis tools. Such initiatives by themselves, however, neither account for the need to train and motivate individuals to make use of these enhanced information environments nor insure that these individuals have the authority to effect decisions or actions subsequently taken. Further, if significant, systematic deficiencies exist in a company's business model, organization design or management capabilities, these informate IT investment initiatives would be difficult to translate into improved performance. The delayed but significant negative market performance results observed with informate IT investment initiatives could thus be interpreted as market analysts waiting to observing if these companies are able to turn themselves around; if performance continues to decline despite these earlier investments, market valuations are dramatically reduced. Clearly, though, such an explanation is conjectural and future research examining the business value of informate IT investment initiatives is needed.

6. Strengths and Limitations

As with any study, there are strengths and limitations to consider. There are two important strengths of this study that differentiate it from others examining the IT investment/firm performance relationship. First, by using data obtained from firms' annual reports, the observed accounts of these firms' IT investment activities are comparable across the sample, stable over time, situated in their business contexts, and at a sufficient level of richness to capture the nature of the IT investment initiatives. Second, the theoretical sampling scheme enabled us to account for two biases that have the potential to introduce considerable noise into collected data sets: industry variance in the salience of IT investment to firms' competitive behaviors, and firm variance in business success (and, hence, the ability to fund IT investments).

This tight research design, however, limited both the number of industries and the number of firms studied. Also, the only IT investment initiatives included in the data are those explicitly mentioned in the firms' annual reports. Whether or not a more complete census of these firms IT investment activities would produce similar results remains an open question. In addition, using annual reports data also limit us from investigating the possible lagged performance impacts of IT investment size. However, this issue is negated to a certain extent as the lag induced by investment size is primarily reflected in the length of the implementation process and the vast majority of IT initiatives reported in the annual reports are completed initiatives; thus, the lag structures investigated should be interpreted as lags between completed implementations and associated performance impacts.

Finally, this use of annual reports as the data source for firms' IT investment initiatives introduced ambiguity as to when an investment actually occurred (early in a fiscal year, late in a fiscal year, etc.) and thus resulted in the most immediate effect examined being that represented by a one-year lag.

7. Conclusion

This study contributes to our understanding of the impact of IT investment on firm performance in two ways. First, the study provides evidence that automate, informate and transform IT investment initiatives are characterized by differential effect patterns regarding distinct facets of firm performance. Second, the results indicate that the lag structures associated with these differential effect patterns also vary in somewhat consistent ways. While our systematic examination of these relationships has provided some fresh insights into the business value of IT, our results have also surfaced some new, important observations regarding market reactions to these differing types of IT investments. We hope our analysis provide scholars with an improved understanding of these relationships and encourages further study into the anomalies that were surfaced.

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APPENDIX

CODING RULES, EXAMPLES OF IT SIGNALS AND CODING RATIONALE

Definitions:

Automate: Replace human labor by automating business processes.

Informate Up/Down: Provide data/information to empower management, employees, or customers.

Transform: Fundamentally alter traditional ways of doing business by redefining business processes and relationships.

Rules:

1. Code at the level of the paragraph, the appropriate code is the highest level (automate, informate, transform) usage of IT indicated in the paragraph.
2. If there is not enough detail to determine the nature of the business IT-enablement involved (such a discussion could be based on altering a manual system), no code is assigned. If there is enough detail to determine that business IT-enablement is involved but not enough to distinguish automate, informate or transform, assign a code of automate.
3. Code multiple instances of the same issue but only if each instance includes enough detail about the IT issue to assign a code (in other words, do not assign a code based on information provided in other paragraphs).
4. Do not code anything related to year 2000 preparedness
5. Do not code information about information technology that is embedded in industrial technology.
6. Providing a new channel for old information is automate (i.e., using technology to provide traditional services to the deaf, providing an on-line chat capability where media alternatives have been available, etc.)
7. IT providing new information to customers: informate.
8. IT creating new information flows: informate.
9. IT changing the way a marketplace operates: transform
10. IT providing a new capability or a new service that restructures the product-market: transform.
11. New IT-based products typically transform.
12. IT-related alliances:
    a. Strategic alliances or strategic acquisitions are typically transform;
    b. Marketing alliances are typically automate (e.g., joining Yahoo!);
    c. Global alliances (i.e., partnering to gain access to a new geographic market) should not be coded unless the alliance was driven by a specific IT-related objective;
    d. Outsourcing is generally not a strategic alliance; thus, it would typically be coded as automate.
13. Adding a new product, even through an IT channel, is not be coded. For instance, selling a new mutual fund electronically would not be coded if the electronic sales channel already existed; however, initially building the electronic sales channel is coded as automate.

Examples of IT Signals and Rationale

Transform IT Investment Initiative (in METAL Industry)

Weirton Steel Corporation, Annual Report, 1998, pg. 2-3.

In 1998 we made significant strides in this direction: Introduction of MetalSite L.P. (www.metalsite.net), a revolutionary partnership with LTV Steel and Steel Dynamics to establish an Internet-based marketplace for the secure online purchase of metals.

Rationale: Rules 10 and 12a. The introduction of this web-site is a partnership, hence a strategic alliance (rule 12a) and also is referred to as "revolutionary" and impacts the marketplace (rule 10). Transform, thus, is the appropriate code.

Informate IT investment Initiative (in SPECIALTY RETAIL Industry)

Charming Shoppes, Inc. Annual Report, 1999, pg. 18

Through our proprietary credit card, third part credit cards and cash customers, we have compiled and maintain a database of more than 18 million names. This data helps us to micro-merchandise, develop product assortments, and respond to customer preferences in each mark. We also micro-market to specific customers based on their shopping habits, products they like, and sizes they wear. Our card program includes cards for Fashion Bug, Catherine's Plus Sizes, and The Answer customers, and ranks as the 17th largest proprietary credit card program in the nation.

Rationale: Rules 1 and 8. While this initiative may also reflect automate technology, the focus is on providing new information to enhance decision making (rule 8). Informate, the higher of automate and informate, thus is the appropriate code.

Automate IT Investment Initiative (in SPECIALITY RETAIL Industry)

Syms Corporation, 1996 Annual Report, pg. 1

Our information services and finance groups successfully implemented a computerized retail stock ledger system in January 1995. As a result, we have been able to more accurately evaluate our inventory movement, develop gross margin figures, prepare future merchandising plans and develop the vital information to prepare our financial and merchandise statements.

Rationale: Rule 4. Clearly, new IT has been implemented but the discussion indicates that they have automated existing manual processes (rule 4) rather than created new information. Automate thus is the appropriate code.