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13P. An Empirical Study of the Relationship Between Information Technology and Firm Performance

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Abstract
Since the issue of the productivity paradox was first raised in the early 1990s, a vast amount of empirical research has been done on the performance impact of IT. Much existing research has focused on IT investment, even though value creation from IT depends largely on how it is used in organizations. By focusing on innovative uses of IT, this research empirically examines the relationship between IT innovation and firm performance. It uses Information Week’s annual data set of innovative IT users and the Compustat database. To construct a measure of IT innovation, we develop a second-order construct from four IT innovation variables (technology strategy, e-business strategy, business practices, and customer knowledge) by conducting exploratory factor analysis. As measures of firm performance, we employ Tobin’s q, return on assets, and revenue per employee. Our results show that there is a strong positive relationship between IT innovation and firm performance as measured by Tobin’s q and revenue per employee. By using IT innovation data, this research demonstrates that innovative use of IT is an important link to IT value, which seems to be missing in the literature.

Keywords
Information Technology Innovation, Firm Performance, Tobin’s q, Organizational Changes

1. Introduction
The question of whether information technology (IT) contributes to firm performance has been debated extensively since the early 1990s. A vast amount of empirical research has been done on the performance impact of IT, with a central focus on solving the productivity paradox raised in the early 1990s (Bharadwaj & Bharadwaj & Konsynski 1999, Brynjolfsson 1993, Brynjolfsson & Hitt 1996, Brynjolfsson & Yang 1998, Santhanam & Hartono 2003, Shin 2001, 2006, Tam 1998). Much of this research has focused on IT investment, although creating value from IT investment depends largely on how it is used in organizations.

IT improves information sharing, decision-making, coordination, market orientation, product quality and variety, timeliness, customization, and convenience. Most of these benefits, however, might be difficult for companies to capture as direct economic value unless they make changes to processes, structures, and strategies. Simply putting money into IT does not automatically create economic value. The creation of value from IT investment depends largely on how it is used in organizations.

This research empirically examines the relationship between IT innovation and firm performance. IT innovation is an integrative concept that includes not only IT investment but also organizational changes in business processes and structures, which are complementary to IT investment. We employ the Information Week’s annual data set of innovative IT users and
the Compustat database. Information Week has identified 500 companies each year as “innovative IT users.” Information Week’s selection of the companies was not determined by how much IT was purchased, but by how companies use IT in their organizations. The data set includes IT innovation categories for each firm, such as technology strategy, e-business strategy, business practices, and customer knowledge.

2. Information Technology Innovation and Firm Performance

Organizational innovation theory defines innovation as adoption of a new idea, practice, or behavior (Daft 1978, Rogers 1995). Rogers (1995) argues that it matters little whether an idea is objectively new as measured by the lapse of time since its first use or discovery. It is the perception of newness that counts, rather than whether the idea is new to the world (Lyytinen & Rose 2003). Thus, if an idea seems new, it is an innovation. When narrowly defined, innovation can be seen as the first or early use of a new idea (Becker & Whisler 1967), and an innovator is considered as the first or early adopter of an innovation (Swanson 1994).

We define IT innovation here as the early adoption and use of new information technologies and business practices. It consists of not only technological innovation but also organizational innovation. According to Lyytinen and Rose (2003), IT innovations involve only a technological component in their simplest form, such as changes in hardware and software new to adopters, but they are often augmented with complementary organizational innovations including new forms of cognition, behavior, business process, and organizational structure. In the process of IT innovation, information technologies can be reinvented to adapt to existing organizational arrangements, but they can also transform organizational practices and structure.

Swanson’s Tri-Core model of information systems (IS) innovation (1994) classifies IS innovation into three categories: Types I, II, and III. According to Swanson (1994), Type I innovation is process innovation restricted to IS functional tasks, such as relational databases and CASE. Type II innovation is the use of IS to support administrative tasks, such as finance, accounting, and payroll. Type III innovation integrates IS with core business processes, such as enterprise resource planning (ERP), supply-chain management (SCM), and customer relationship management (CRM). Swanson (1994) argues that Type III innovations affect the whole business and have strategic relevance by offering competitive advantage to firms that are early adopters.

Extending Swanson’s model, Lyytinen and Rose (2003) propose the three-set model of IT innovation, which includes three forms of IT innovations—systems development innovation, service innovation, and IT base innovation. Systems development innovation involves changes in systems development processes, such as new development tools or programming teams (Type I innovation in Swanson’s model). Service innovation refers to outcomes of development processes (i.e. services), which include the use of IT to support administrative core activities, such as accounting (Type II innovation in Swanson’s model) and innovations in which the use of IT affects either business functions or core business processes (Type III innovation in Swanson’s model). IT base innovation refers to changes in computing capability, which are often a necessary (but not sufficient) antecedent for other forms of IT innovation. It includes new software and hardware architectures and services, and new telecommunication capability.

Lyytinen and Rose (2003) argue that IT base innovations are leveraged by complementary organizational innovations. Swanson and Ramiller (2004) also argue that an organization is
mindful in innovating with IT when it pursues innovation with reasoning grounded in its own organizational facts and specifics, such as objectives, structure, and processes, and the organization’s relationship to the larger environment. Deficient understanding – handmaiden to mindlessness – is a prime cause of failure with IT investments.

According to Schumpeter (1934), innovation is the source of value creation and competitive advantage. Schumpeterian innovation theory emphasizes the importance of technology and considers innovative use of technology as the foundation of new product development and production methods (Zhuang 2005), which eventually destroy existing competencies and break down existing rules of competition. Porter and Millar (1985) argue that innovation can help firms alter the rules of competition, affect industry structure, and develop new ways of outperforming rivals, thus creating competitive advantage.

As discussed above, IT innovation can create value and offers competitive advantage to firms. Accordingly, we propose that IT innovation embracing both technological and organizational innovations has a positive impact on firm performance.

3. Data Sources, Case Examples, and Measures

3.1 Data sources
This research employs the Information Week’s annual data set of innovative IT users for two years: 2000 and 2001 and the Compustat database. Information Week has rated companies by the quality of IT innovations (technological, procedural, and organizational innovations), not by the amount of IT spending. The data set includes four IT innovation categories: technology strategy, e-business strategy, business practices, and customer knowledge. These categories are scored at three levels (gold, silver, and bronze) for each firm based on “its early adoption and creative use of technologies and business practices” (Weston 2000). This specification is consistent with the IT innovation literature, which defines IT innovation as the first or early adoption and use of new information technologies and business practices (Swanson 1994, Lyytinen & Rose 2003).

3.2 Case examples of information technology innovation
In an attempt to understand the nature of IT innovation, we examine several case examples of IT innovations undertaken in companies selected as innovative IT users by the Information Week. Evidence from these examples can serve as indicators of IT innovation. For example, the operational CRM of Harrah’s Entertainment indicates they have introduced IT innovations that have been very effective. By analyzing not only historical customer data but also customer behavior in real-time, the company has been able to provide better customer service and find ways to add value to customer experience, such as surprising them with special gifts and offers at the moment they hit a new royalty status (new business practices). The operational CRM has also helped to address service problems in near real time. Harrah’s

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1 The Information Week 500 data set has often been used by researchers. While the IT innovation variables are qualitative (perceptual) measures, their nomological validity was demonstrated by Shin (2004). He further argued that the survey instrument was practically relevant since the editing team of Information Week 500 has had experience in designing the instrument and collecting the data annually for over a decade. In general, large-scale secondary survey data such as the data set used in this study provide several advantages, such as providing a longitudinal database on various constructs not often available in other data sources, better response rate, participation of knowledgeable industry analysts and executives, and corroboration through qualitative reports and case studies (Bharadwaj 2000).
changed CRM from something used to analyze customer visits into a tool for personalized, in-the-moment interactions (Anonymous 2006b).

Motorola’s global SCM system provides another example illustrating how a firm uses IT innovatively. By integrating foreign suppliers into its global supply chain, the company designs, builds, and distributes products globally to meet growing customer demand. It also uses the Six Sigma program in conjunction with business process management software to design and automate solutions. According to Information Week (2006a), while many companies find offshore outsourcing to be an effective strategy for greater efficiency, some companies go beyond offshore outsourcing to pursue global opportunities. Positioning close to consumer markets, these companies focus on product design, sales and distribution, and leverage innovation of others (component suppliers) to enhance their products. Such global strategies include everything from having workers or subsidiaries outside the U.S to employing non-U.S. suppliers to build a global supply chain and coordinate overseas operations in real time.

Another company pursuing global opportunities through innovative IT use is Arrow Electronics, a global electronic components distributor. The company implemented a global wide area network (WAN) to eliminate the lag between requests for data and the beginning of data transfer between sales offices in regions outside the U.S. and its New York data center (Chabrow 2006). The company’s global WAN established a direct connection – one-hop connectivity – between New York and all its sales offices.

Sun Microsystems’ One Touch Program provides another illustration of IT innovation. The company operates a single global instance of its ERP applications, SCM software, and demand planning applications. The company simplified its IT architecture on the back end, giving it speed and flexibility. Using the One Touch System, the company can configure products for each order, rather than filling orders using predetermined products that may or may not be in its warehouses. A chief benefit for the company is the ability to close distribution centers in Asia, Europe, and the U.S. and cut inventory-handling costs (Whiting 2006).

In summary, the case examples of the operational CRM, the global SCM system, the global WAN, and the ERP systems blended with SCM and demand planning systems show that firm performance can be improved by IT when IT is used innovatively, that is, in conjunction with new business practices, strategies, and structures.

3.3. Measures
By treating the four IT innovation categories (technology strategy, e-business strategy, business practices, and customer knowledge) as first-order factors of IT innovation, we develop a second-order construct of IT innovation and use it as a measure of IT innovation. To construct a measure of IT innovation, we assign the numbers, 3, 2, and 1 to gold, silver, and bronze respectively and develop a second-order construct from the four IT innovation variables by doing exploratory factor analysis (principal component analysis with equimax rotation). According to Zhu and Kraemer (2005), such a second-order approach represents a theoretically strong basis for capturing complex measures. This approach is more rigorous than simply adding up the factors because it takes into account the appropriate weight of each factor (Zhu 2004).
In order to examine the impact of each of the first-order IT innovation factors, we also construct measures of the four IT innovation categories by using dummy variables. We use two dummy variables for each category since there are three different classes (gold, silver, and bronze) for the categories (Gujarati 1988). For dummy one ($D_1$), a value of 1 is given to gold and a value of 0 is given to both silver and bronze. For dummy two ($D_2$), a value of 1 is given to silver and a value of 0 is given to both gold and bronze. Such an assignment of the dummy variables treats the bronze class as the base category. The use of dummy variables for the first-order factors complements the use of the second-order construct of IT innovation.

As measures of firm performance, we employ Tobin’s $q$, return on assets (ROA), and revenue per employee. Data items are obtained from the Compustat database for the same firms included in the Information Week’s data set.

4. Methodology and Model
To analyze the relationship between IT innovation and firm performance, we perform a regression analysis of the combined data set for the two years of 2000 and 2001.

The model measures the relationship between IT innovation and firm performance as measured by Tobin’s $q$, revenue per employee, and ROA with various control variables, including industry and year. The model also includes a one-year lagged variable of firm performance to control for past performance since the performance impact of IT innovation can be overestimated if there is no control for past performance (Santhanam & Hartono 2003, Tanriverdi 2006, Zhu 2004). The number of employees is used as a control variable for firm size. We take the log of the number of employees in order to get a normal distribution for the value. We do not make the log transformation for other variables because they are normalized by taking ratio value. Dummy variables for each industry are categorized by the SIC code.

\[
\text{PERF}_{i,t} = \beta_0 + \beta_1 \text{IT}_{i,t} + \beta_2 \text{RDIV}_{i,t} + \beta_3 \text{URDIV}_{i,t} + \beta_4 \text{CAP}_{i,t} + \beta_5 \text{PPERF}_{i,t-1} + \beta_6 \text{EMP}_{i,t} + \\
\beta_7 \text{INDUSTRY}_{i,t} + \beta_8 \text{YEAR}_{i,t} + \epsilon
\]

where for firm $i$ in year $t$:

\begin{align*}
\text{PERF}_{i,t} & = \text{Tobin’s } q, \text{ revenue per employee, and ROA} \\
\text{IT}_{i,t} & = \text{Second-order factor of IT innovation} \\
\text{RDIV}_{i,t} & = \text{Entropy index of related diversification} \\
\text{URDIV}_{i,t} & = \text{Entropy index of unrelated diversification} \\
\text{CAP}_{i,t} & = \text{Capital investment/total assets} \\
\text{PPERF}_{i,t-1} & = \text{Past performance} \\
\text{EMP}_{i,t} & = \text{Ln (employees)} \\
\text{INDUSTRY}_{i,t} & = \text{a dummy for industry} \\
\text{YEAR}_{i,t} & = \text{a dummy for year} \\
\epsilon & = \text{an error term with zero mean}
\end{align*}

IT stands for IT innovation. It is replaced by two dummy variables ($D_1$ and $D_2$) when we analyze the performance impact of each IT innovation category. The corresponding model is shown below:

\[
\text{PERF}_{i,t} = \beta_0 + \beta_1 D_{1i,t} + \beta_2 D_{2i,t} + \beta_3 \text{RDIV}_{i,t} + \beta_4 \text{URDIV}_{i,t} + \beta_5 \text{CAP}_{i,t} + \beta_6 \text{PPERF}_{i,t-1} + \beta_7 \text{EMP}_{i,t} + \\
\beta_8 \text{INDUSTRY}_{i,t} + \beta_9 \text{YEAR}_{i,t} + \epsilon
\]
RDIV and URDIV stand for the Entropy index of related and unrelated diversification. CAP denotes capital intensity. Performance represents firm performance measures that will be replaced in turn by each of the three performance variables: Tobin’s q, revenue per employee, ROA. When Tobin’s q and revenue per employee are employed as dependent variables, the one-year lagged variable of ROA is employed as a past performance variable. When ROA is employed as a dependent variable, the one-year lagged variable of Tobin’s q is employed as a past performance variable. EMP denotes the log of the number of employees. INDUSTRY and YEAR denote dummy variables for industry and year, which control for differences in industry characteristics and market trends respectively. $\varepsilon$ is the residual term with zero mean, which captures the net effect of all unspecified variables.

5. Results
5.1 Analysis with the second-order factor of IT Innovation
The second-order construct of IT innovation is estimated by conducting exploratory factor analysis. Table 1 shows the estimation of the second-order construct. The component loadings to the four first-order factors are of high magnitude, greater than .7, the cutoff suggested by Chin (1998). Cronbach’s $\alpha$ is also greater than .7, providing satisfactory reliability (Nunnally 1978). The average variance extracted is greater than the suggested cutoff of .5 (Bagozzi & Yi 1988, Fornell & Larcker 1981). This indicates that variance in each of the four first-order constructs is sufficiently accounted for by the second-order construct.

<table>
<thead>
<tr>
<th>Second-order construct</th>
<th>First-order construct</th>
<th>Component loadings</th>
<th>Average variance extracted</th>
<th>Cronbach’s $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT innovation</td>
<td>Technology strategy</td>
<td>.720</td>
<td>.54</td>
<td>.71</td>
</tr>
<tr>
<td></td>
<td>E-business strategy</td>
<td>.746</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business practices</td>
<td>.712</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Customer knowledge</td>
<td>.746</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Extraction method – principal component analysis with equimax rotation

Table 1: Estimation of the Second-Order Construct

Table 2 shows correlations of IT innovation and firm performance as measured by revenue per employee, Tobin’s q, and ROA. The results show that IT innovation has a strong positive relationship with revenue per employee ($p<.05$) and Tobin’s q ($p<.05$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Revenue per employee</th>
<th>Tobin’s q</th>
<th>ROA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobin’s q</td>
<td>-.053</td>
<td>(772)$^1$</td>
<td></td>
</tr>
<tr>
<td>ROA</td>
<td>.005</td>
<td>.421***</td>
<td>(778)</td>
</tr>
<tr>
<td>IT innovation</td>
<td>.088*</td>
<td>.094*</td>
<td>.000</td>
</tr>
</tbody>
</table>

Key: *** ($p<.001$), * ($p<.05$)

$^1$ The values in parentheses are the number of observations.

Table 2: Correlations
Our regression results (Table 3) show that IT innovation is positively associated with firm performance as measured by Tobin’s q and revenue per employee, but not by ROA. The positive relationship is significant for both performance variables. The coefficient of IT innovation indicates that the null hypothesis of zero effect of IT innovation can be rejected at a .05 confidence level for both Tobin’s q and revenue per employee. The F values suggest that the overall model is statistically significant at a level of .001. The insignificant result on ROA implies that IT innovation may have little impact on how effectively a firm uses its capital investments or assets. One possible reason is that IT investment is small compared to total assets or capital investments. As a result, the performance impact of IT innovation may not be detectable with the ROA measure. Capital intensity, however, is strongly associated with an increase in ROA. Unrelated diversification is strongly associated with a decrease in Tobin’s q. Its coefficient is not significant for other performance measures. It indicates that companies do not improve their value by diversifying their operations into unrelated markets.

### Table 3: Regression Results

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Tobin’s q&lt;sub&gt;i&lt;/sub&gt;</th>
<th>Revenue per Employee&lt;sub&gt;i&lt;/sub&gt;</th>
<th>ROA&lt;sub&gt;i&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Innovation&lt;sub&gt;t&lt;/sub&gt;</td>
<td>.104* (2.52)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>.107* (2.56)</td>
<td>-.012 (.28)</td>
</tr>
<tr>
<td>RDIV&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-.059 (-1.43)</td>
<td>.024 (.58)</td>
<td>.028 (.65)</td>
</tr>
<tr>
<td>URDIV&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-.174*** (-4.08)</td>
<td>.048 (1.10)</td>
<td>.070 (1.55)</td>
</tr>
<tr>
<td>Capital Intensity&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-.033 (-.71)</td>
<td>-.134** (-2.70)</td>
<td>.253*** (5.87)</td>
</tr>
<tr>
<td>EMP&lt;sub&gt;t&lt;/sub&gt;</td>
<td>.107* (2.54)</td>
<td>-.281*** (-6.45)</td>
<td>.079* (1.79)</td>
</tr>
<tr>
<td>ROA&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td>.430*** (8.98)</td>
<td>.075 (1.51)</td>
<td>.263*** (5.80)</td>
</tr>
<tr>
<td>Tobin’s q&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Controls</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
</tr>
<tr>
<td>Adjusted R&lt;sup&gt;2&lt;/sup&gt;</td>
<td>27.9%</td>
<td>14.2%</td>
<td>22.1%</td>
</tr>
<tr>
<td>F Statistic</td>
<td>15.47***</td>
<td>7.99***</td>
<td>11.57***</td>
</tr>
<tr>
<td>N</td>
<td>449</td>
<td>508</td>
<td>448</td>
</tr>
</tbody>
</table>

*** (p<.001), ** (p<.01), * (p<.05), + (p<.10)

1 Standardized coefficients are reported. 2 The values in parentheses are t-statistics.

### 5.2 Analysis with the four first-order factors of IT innovation

Our results (Table 4) show that the IT innovation factors of technology strategy, business practices, and customer knowledge are strongly associated with an increase in firm performance as measured by Tobin’s q. The results indicate that firms highly rated (scored as gold) in the categories of business practices and customer knowledge achieve better performance than firms rated as bronze (the base category). In the case of technology strategy, firms rated as silver achieve better performance than firms rated as bronze. The factor of e-business strategy does not make any difference in performance as measured by Tobin’s q (Table 4). However, it is strongly associated with an increase in firm performance as measured by revenue per employee (Table 5). The results imply that innovations in e-business increase labor productivity by facilitating better supply chain management and enterprise-wide coordination. Customer knowledge and business practices are also positively associated with firm performance as measured by revenue per employee. The results imply that firms improve their performance by meeting customer needs better, e.g., the use of CRM systems, and incorporating new business practices.
Compared to the results obtained for Tobin’s q and revenue per employee, the results for ROA (Table 6) show that the first-order factors of IT innovation are not associated with improved firm performance as measured by ROA. These results are consistent with the ones obtained from the analysis of the second-order factor.
Adjusted $R^2$ | 22.3% | 22.1% | 21.9% | 22.2%
F Statistic | 10.92*** | 10.75*** | 10.67*** | 10.83***
N | 449 | 449 | 449 | 449

*** (p<.001), * (p<.10)

1 Standardized coefficients are reported. 2 The values in parentheses are t-statistics.

Table 6: Results for ROA

6. Conclusions
This study empirically examines the relationship between IT innovation and firm performance. As a measure of IT innovation, we develop a second-order construct from the four first-order IT innovation factors by conducting an exploratory factor analysis. As measures of firm performance, we employ Tobin’s q, revenue per employee, and ROA. Our results show that there is a strong positive relationship between IT innovation and firm performance as measured by Tobin’s q and revenue per employee. The analysis with the four first-order factors of IT innovation provides results consistent with the ones obtained from the analysis with the second-order factor of IT innovation.

This research views generating value from IT as a complex process embracing both the adoption of new information technologies associated with new business practices and structure. By using the IT innovation data that entail both technological and organizational innovation, our work demonstrates that innovative use of IT is an important link to IT value, which seems to be missing in the literature. Since simply putting money into IT does not automatically improve firm performance, the use of IT innovation as a measure of IT, instead of IT investment, can provide a means of examining the true value of IT.

References
Anonymous (2006b) “20 great ideas from InformationWeek 500 companies”, Information Week, September 12.