Empirical Evidence on Swanson’s Tri-Core Model of Information Systems Innovation

Varun Grover • Kirk Fiedler • James Teng
University of South Carolina, Management Science Department, Columbia, South Carolina 29208
vgrover@darla.badm.sc.edu
fiedler@darla.badm.sc.edu
fsujteng@darla.badm.sc.edu

Research in IS innovation has been isolated and fragmented. These studies typically examine single innovations and do not effectively integrate notions of IS innovation with organizational innovation. Swanson (1994) extends the prior dual-core model of innovation into a tri-core model specifically for the unique nature of IS innovation. This model provides a useful typology of IS innovation that can form the foundation for innovation theory in this important area. In this paper we present Swanson’s tri-core model of IS innovation along with preliminary data to test aspects of the model proposed by Swanson. Adoption of ten IS innovations is studied using two analyses, one based only on adopter sub-samples and the other using a more rigorous treatment of nonadopters based on survival analysis. The objective of this study is simple—to test theory and encourage continued focused inquiry in IS innovation. The results of this study provide partial support for the proposed hypotheses, leading us to conclude on an optimistic note regarding the viability of this model as an integrating framework for IS innovation.
(IS Innovation; Organizational Innovation; Tri-Core Model; Technical Innovation; Survival Analysis; Innovation Theory)

Introduction
The rapid penetration of information technology into the core elements of organizational structure and processes is enabling changes that are profound and significant. The flexibility offered by today’s computing and communication systems can enable a more proactive role for organizations to adopt and diffuse these systems in a manner that enhances productivity. While the pace of technological change inhibits systematic planning for such systems, there is significant opportunity to leverage today’s information technology as contrasted with the relatively inflexible centralized computing environment of just 20 years ago. Therefore, the study of Information Systems (IS) and technology-based innovation in an organizational context is crucial if organizations are to respond to such opportunities—and failure to do so threatens survival in our increasingly information intensive context.

Swanson (1994) recently proposed a model for information systems innovation in an organizational context. We view this as a significant development for a number of reasons. First, while the study of organizational innovation has been vast and diverse, the study of IS innovation has, until recently, been sparse and uncoordinated. This is of particular concern, given the pervasiveness and integrative nature of information technologies. Second, theory development is worthwhile, since it provides coherence to research agendas and facilitates a cumulative body of knowledge. The number of meta-analyses in general innovation are all motivated by the need for theory (e.g., Damapour 1987, 1991; Kwon and Zmud 1987;
Tornatzky and Klein (1982). Third, most IS innovation work studies specific IS innovations, using contextual factors from other innovation studies. This implicitly presumes that all IS innovations are homogenous in their propensity to be adopted or diffused and can be modeled using a set of common constructs. Given the diversity reflected in today's technologies, this presumption needs to be examined, and Swanson's model attempts to do that. Fourth, as pointed out by Swanson, very few studies look at the relationship between IS innovation and business innovation. In an environment where information technology is providing the impetus for organizations to reinvent the way they do business, such relationships are critical. Further, studying such relationships can help bridge the gap between organizational and IS theory.

In this paper we present Swanson's tri-core model of IS innovation along with preliminary data to test certain aspects of the model. Adoption of ten IS innovations is studied using two analyses, one based on only adopter subsamples, and the other using a more rigorous treatment of nonadopters based on survival analysis. The objective of this study is simple: to test theory in a methodologically appropriate manner and to encourage continued inquiry in IS innovation. It is our belief that only through further synergistic deductive and inductive studies in this area will consistent theory begin to emerge. The evidence presented affirms the viability of Swanson's model as an appropriate vantage point from which to begin building a theory of IS innovation. Further avenues for refinement of the model are also discussed.

The Swanson Model

Some of the most significant early work on organizational innovation was by Daft (1978), who proposed a dual-core model of innovation—distinguishing between innovations that focus on the technical core and those that focus on the administrative core. Technical innovations relate to the technical system of the organization or the primary work activity. These may or may not involve technology (e.g., a new service or product). Administrative innovations relate to the social system of rules, roles, procedures, and structures in the organization (e.g., a new way to carry out a decision). Daft (1978) concluded that, in all likelihood, organic structural conditions (i.e., less formal and less centralized) that facilitate innovation in the technical core are the opposite of those required for the administrative core. Damanpour and Evan (1984), in their study of public libraries, concluded that while most innovation studies focus on technical innovations, a combination of changes in the social and technical systems helps performance. Further evidence of these distinctions was found in a later study by Damanpour (1987).

Swanson (1994) argues that the dual-core model is inadequate for the study of IS innovation. IS spans both the technical and administrative cores and is therefore unlikely to be characteristic of innovation local to either. Further, IS involves communication technology and the ability to share information resources in both the technical and administrative cores. These effects can permeate beyond the IS unit, facilitating innovation in the broader business unit. Therefore, Swanson proposes the addition of a third core, the functional IS core, to the dual-core model to link the technical and administrative cores.

The tri-core model proposed by Swanson is illustrated in Figure 1. The central cylinder of the figure represents the IS products and services provided, typically, by the core IS function that might have centralized or distributed responsibility within the organization. The model distinguishes three fundamental types of IS innovations (Types 1, 2, and 3) within the...
organization. Type 1 innovation is closest to the functional core involving the IS products themselves. These innovations could be either a new IS administrative arrangement that supports IS work (Type 1a) or an innovation that focuses directly on the technical IS task (Type 1b). Type 2 and Type 3 innovations extend IS innovation beyond the confines of the IS function into the general organizational environment. They involve application of new IS products and services to the administrative core of the business (Type 2) or the core business technology (Type 3). The administrative core of the business provides the administrative processes and infrastructure that support the business and its products and services. Type 3 innovation can be further subdivided based on its application to various aspects of the core business: the core work processes (Type 3a), the products and services themselves (Type 3b), and the integration or coordination of the business with its external constituents (Type 3c). Table 1 summarizes the types of innovations in the model and provides examples for each type.

Swanson suggests that it is useful to distinguish between IS innovations in this way, where each IS innovation could comprise information technology

<table>
<thead>
<tr>
<th>Table 1</th>
<th>IS Innovation Taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtype</td>
<td>Innovation Core</td>
</tr>
<tr>
<td>Type 1a</td>
<td>IS Administrative Process Innovation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td>IS Product and Business Administrative Process Innovation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 3a</td>
<td>IS Product and Business Technological Process Innovation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 3b</td>
<td>IS Product and Business Product Innovation</td>
</tr>
<tr>
<td>Type 3c</td>
<td>IS Product and Business Integration Innovation</td>
</tr>
</tbody>
</table>
and/or work organizational features. The motivators of each type of innovation might be distinct, with innovations central to IS functionality having professional and resource based motivators, while innovations central to business functionality (i.e., Type 3) may have organizational and strategic motivators. However, the unique integrated nature of IS makes it necessary to recognize the relationships between the three types of innovations, thereby bridging the gap between the IS function and the general organization context (which is ignored in the earlier dual-core model). Therefore, Swanson recognizes weak order effects emanating from the functional core toward the business core (i.e., Type 1 to Type 3) and strong order effects emanating the other way (i.e., Type 3 to Type 1). In other words, IS process innovation might have some effect on the core and administrative aspects of the business, but it will not compel business innovation. However, business innovation (e.g., Type 3), being integral to the core line function or products of the business, might compel changes and innovation in the administrative structure of the business or the IS function itself. Implicit in the discussion of the model is the notion of business value, which ultimately justifies any innovation.

Hypotheses Proposed
A number of hypotheses are proposed by Swanson in order to study the adoption and diffusion of IS innovations. While the variables proposed are not new, they have never been examined within a coherent context of IS innovation. It should be noted that Swanson's treatise provides rich insights into various aspects of the model. However, in this study, only the central aspects of the model which involve the distinction between types of IS innovation will be examined.

The hypotheses look at the earliness of adoption as the dependent variable. Here, consistent with Rogers (1983), early adopters of IS innovation are innovators. Below, we briefly describe the hypotheses that are adapted directly from Swanson's work. Reference to prior innovation work that has studied similar variables is also provided.

The size of the IS unit and host organization are proposed as facilitators of innovative behavior. Larger organizations tend to be internally diverse, have more resources, have more boundary spanners, and attract management consultants for organizational change, all of which are known to be important to innovation. Swanson indicates that Type 1 innovation will depend on gateways to learning based on IS unit size, while Type 2 and Type 3 innovation have stronger relationships with host organization size. Relationships between size and adoption of both technical and administrative innovation have been found in prior empirical work (e.g., Moch and Morse 1977, Kimberly and Evansko 1981, Zmud 1984).

H1a. Early adoption of Type 1 innovation is positively related to the size of the IS unit.

H1b. Early adoption of Type 2 innovation is positively related to the size of the host organization.

H1c. Early adoption of Type 3 innovation is positively related to the size of the host organization.

Slack resources are also proposed to be significant for the IS and organizational unit. Such slack allows units to experiment and pilot projects in advance of an actual need, bear costs of instituting innovation, and absorb failure (Rosner 1968). Swanson suggests that "slack in the IS unit will buffer it from the periodic cost reduction demands of the business" (p. 1081), thereby enabling Type 1 innovation. This is especially true where IS is centralized. On the other hand, organizational slack (of the host organization) will foster Type 2 and Type 3 innovation. Evidence of slack as an important innovation variable exists, and there is some indication that slack facilitates technical innovation more than administrative innovation (Damornpour 1987).

H2a. Early adoption of Type 1 innovation is positively related to availability of slack resources in the IS unit.

H2b. Early adoption of Type 2 innovation is positively related to availability of slack resources in the host organization.

H2c. Early adoption of Type 3 innovation is positively related to availability of slack resources in the host organization.

Swanson suggests that an elaborate, but not aged, set of work technologies and application portfolio will
provide the impetus for business innovation (Type 2 and Type 3). Variables such as specialization and differentiation have been used in innovation studies to reflect the diversity of technological knowledge in a firm (e.g., Kimberly and Evanisko 1981). These variables facilitate exposure to more technologies and thereby to more innovative applications. A similar argument can be forwarded here for information technology. The diversity of the (newer) information technology portfolio can facilitate Type 2 and Type 3 innovation. The effects of this diversity are more pronounced when the integrative nature of information technology is considered, which can help support the core business and administrative structures of the firm.

H3a. Early adoption of Type 2 innovation is positively related to the diversity of the information technology portfolio in the organization.

H3b. Early adoption of Type 3 innovation is positively related to the diversity of the information technology portfolio in the organization.

The professional orientation of the IS unit is defined in terms of its affiliation with its professional environment. The closer its coupling with its technological and professional environment for its knowledge base, the more likely the early adoption of Type 1 and Type 2 innovation, which are closer to the functional IS core. As discussed by Swanson, highly professional orientations value “leading edge” technology and “recognize the rapidity with which their expertise is subject to obsolescence” (p. 1082). These hypotheses are not inconsistent with innovation studies—which have shown that professionalism is directly related to innovations closer to the (central) technological core (Daft 1978, Zmud 1984).

H4a. Early adoption of Type 1 innovation is positively related to the professional orientation of the IS unit.

H4b. Early adoption of Type 2 innovation is positively related to the professional orientation of the IS unit.

The final hypothesis reflects the strategic orientation of the IS group within the organization. This variable has been subject to much discussion within the context of strategic IS (Johnston and Carrico 1988). Type 3 innovations reflect characteristics of strategic IS in that they are often integral to core products and processes and usually involve interorganizational relationships. Therefore, early adoption of Type 3 innovation is more likely where IS is of strategic importance to the host organization.

H5. Early adoption of Type 3 innovation is positively related to the strategic importance of the IS unit to the host organization.

1. Selecting Type 1, 2, and 3 Innovations

This study tested the proposed hypotheses. Critical to this testing was the identification of IS innovations that fall distinctly into the categories proposed in the model. Based on the guidelines and examples provided by Swanson, ten IS innovations were selected in the three categories. Multiple innovations within each category (1, 2, and 3) were selected in order to obtain a broader representation of the category.

Four Type 1 innovations were chosen. Swanson defines Type 1 innovation as a change in “the management and administrative support of IS work, as with departmentalization of the software maintenance function.” The Type 1a (IS administrative process innovation) chosen was IS outsourcing. A compelling argument for IS outsourcing as an administrative process innovation has been provided by Loh and Venkatraman (1992). They indicate that it involves a significant shift in the mode of governance where the IS managers take on new administrative roles in overseeing outsourcing contracts and new routines are used to deal with the IT marketplace. Type 1b innovation deals with the IS task itself where “the nature of IS work is changed.” Three innovations were selected as Type 1b: Computer Aided Software Engineering (CASE), Object Oriented Programming Systems (OOPS), and large scale relational Data Base Management Systems (DBMS). All three are integral to changing IS work. CASE and OOPS are currently being touted as transforming the development function. DBMS (defined in terms of large scale transactional databases rather than user-oriented PC based systems), while older, was included as it was discussed by Swanson as a Type 1 innovation.
Type 2 innovations apply IS products and services to the administrative core of the business. Examples given by Swanson include financial accounting systems, payroll systems and executive information systems (EIS). In this study, four Type 2 innovations were chosen: EIS, teleconferencing, expert systems, and electronic mail. All four effect the administrative core by facilitating decision processes or accelerating administrative processes.

Type 3 innovations integrate IS products and services into the core work processes (Type 3a), products and services (Type 3b) and external relationships (Type 3c) of the business. CAD/CAM systems (the major component of CIM systems mentioned by Swanson), which are integral to the core design of products, were selected as the Type 3a innovation. EDI systems, which facilitate the coordination between customers and suppliers, were selected as a Type 3c innovation.

The last two columns of Table 1 list the innovations discussed in the Swanson paper and the ones selected for this study. The method used to test the hypotheses proposed with respect to these innovations is described in the next section.

**Methodology**

The objective of this study is to test the theoretical perspectives described in the tri-core model. Preliminary evidence supporting the differential impact of the contextual variables on the types of IS innovations can provide valuable insights for theory building in this area. Toward this end, data were gathered from a large population by using a questionnaire instrument. The target respondent was the senior IS executive. This is consistent with Huber and Power's (1985) recommendation; in the case where one respondent per unit is solicited, it should be the most informed respondent. It was presumed that the corporate senior IS executive would be the most informed respondent regarding IS innovation within the IS function and throughout the host organization.

**Measures**

The instrument we developed included a number of self reported “objective” and “perceived” measures. For each of the IS innovations (i.e., Outsourcing, CASE, OOPS, DBMS, EIS, Teleconferencing, Expert System, E-Mail, CAD/CAM, and EDI) earliness of adoption was operationalized by asking the respondent to indicate the year of first adoption of the innovation. A generic three-stage model of IS diffusion consistent with that proposed by Cooper and Zmud (1990) was used for data collection. Adoption (representing the decision to invest resources in the innovation) was distinguished from “use” and “impact” of the innovation. Data on the use and impact of each innovation were also collected at the same time, and this served to clarify the interpretation of adoption. In the case of outsourcing, the year of the first outsourcing experience was solicited. In all cases, the year of adoption was subtracted from the date the questionnaire was received in order to compute the number of years since adoption.

IS size and organizational size were captured using standard IS budget and organizational revenue measures. Number of employees for the organization was also captured as an alternate measure of size, given increasing divergence of these two measures with current investments in IT and downsizing trends (Brynjolfsson et al. 1994). IS slack was measured as the ratio of IS budget to sales reflecting the amount spent on IS per unit sales. Organizational slack was measured using a perceptual measure of satisfaction with profitability adapted from Venkatraman (1985). This measure is consistent with prior measures of slack as it relates to firm profitability (e.g., Damanpour 1987), and was captured using five items related to satisfaction with: return on investment, net profit, corporate investment, return on sales, and financial liquidity. Technological diversity was assessed through a raw count of adopted technologies from a list of 20 technologies provided. These technologies included a myriad of contemporary hardware and software based information technologies drawn from various technological studies (e.g., Straub and Wetherbe 1990). These technologies included communication technologies (like LAN, client-server computing, EDI, e-mail, etc.), processing technologies (like mainframe computing, etc.).

1In the pretesting of the instrument, interpretation of the term adoption was not a problem. Most executives viewed it as “acquisition” of some hardware and/or software, which was consistent with our interpretation. Also, IS executives were all very familiar with the IS innovations selected.
EIS, mini-computers, work stations, etc.), storage technologies (like relational DBMS, imaging, expert systems, etc.), and development technologies (like object oriented design, CASE, and fourth generation languages). Professionalism or the importance of being on the "leading edge," as discussed by Swanson, was assessed using a two-item measure that examines the importance placed on introducing new information technologies into the organization and scanning the environment for new technological developments. Finally, the strategic importance of IS was gauged using a six-item measure adapted from Premkumar and King (1993) that evaluates statements related to top management commitment to IS, understanding of the role of IS in supporting organizational strategy, identification of IT opportunities to support the strategic direction of the firm, etc.

The instrument was iteratively refined through feedback from twelve IS executives in different metropolitan areas. Seven of these executives were interviewed face-to-face for over one hour each. The feedback resulted primarily in refinement of the technologies and modification of the wording of some items. On final administration the unidimensionality and reliability of the multiple item measures were assessed. All exhibited discriminant and convergent validity through factor analysis and reliabilities were assessed at over 0.80. These measures were deemed adequate given the intent of this study.

Administration
The final instrument was administered to a population of 900 executives drawn from a database of over 5000 executives affiliated with a leading professional publishing and information service firm. This firm compiles and sells information about the subscriber base of the 14 information technology related magazines it publishes. The sample frame requested was for senior IS executives (Director or above) in unique U.S.-based for-profit organizations. As indicated earlier, we believe that these executives would be most informed about IS innovations and their organizational antecedents as described in this study (Huber and Power 1983). From these, only those affiliated with organizations of over $50 million in revenue were randomly selected. The sample frame includes IS executives who represent the majority of larger U.S. firms. However, no assessment of sample bias was made.

Two mailings were sent out, one month apart. Respondents were encouraged to call with any questions they had regarding the instrument. Monetary incentives were provided to encourage responses. Of the 900 initial mailings, 45 were returned and did not reach the targeted individual, while 313 usable responses were obtained, indicating an effective response rate of 36.6%. The industries of the responding firms are provided in Figure 2. Over half the sample is from the financial and manufacturing sectors. Also, over half the sample of responding organizations have over 2500 employees, with about one third having over 5000.

Table 2 describes the adoption profile for each innovation. The third column provides an indication of the average diffusion level of each innovation among potential users in the responding unit at the time of the survey. The numbers indicate that all the innovations had, on average, achieved a significant level of diffusion in their respective organizational units. The next two columns indicate the number and percentage of respondents that had adopted each innovation. OOPS had the least number of adopters (78), while e-mail had the most (241). In all cases, the number of adopters was adequate for statistical analysis. However, alternate treatment of nonadopters was conducted as described in the subsequent sections.
### Table 2: Innovation Profile

<table>
<thead>
<tr>
<th>Innovation Type</th>
<th>Innovation</th>
<th>Average Penetration of Innovation (% of employees who can potentially benefit from the innovation)</th>
<th>Number of Adopters that are using it</th>
<th>Percentage of Adopters of Adopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Outsourcing</td>
<td>n/a</td>
<td>130</td>
<td>41.5%</td>
</tr>
<tr>
<td></td>
<td>CASE</td>
<td>34.4%</td>
<td>115</td>
<td>36.7%</td>
</tr>
<tr>
<td></td>
<td>Object Oriented</td>
<td>34.9%</td>
<td>115</td>
<td>36.7%</td>
</tr>
<tr>
<td></td>
<td>Programming Systems/Design (OODS)</td>
<td>27.9%</td>
<td>78</td>
<td>24.9%</td>
</tr>
<tr>
<td></td>
<td>Large Scale Relational DBMS</td>
<td>54.1%</td>
<td>171</td>
<td>54.6%</td>
</tr>
<tr>
<td>Type 2</td>
<td>Executive Information Systems (EIS)</td>
<td>35.8%</td>
<td>116</td>
<td>37.1%</td>
</tr>
<tr>
<td></td>
<td>Teleconferencing</td>
<td>52.2%</td>
<td>147</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>Expert System</td>
<td>25.2%</td>
<td>88</td>
<td>28.1%</td>
</tr>
<tr>
<td></td>
<td>Electronic Mail (E-Mail)</td>
<td>63.6%</td>
<td>241</td>
<td>77%</td>
</tr>
<tr>
<td>Type 3</td>
<td>CAD/CAM</td>
<td>70.4%</td>
<td>117</td>
<td>37.4%</td>
</tr>
<tr>
<td></td>
<td>Electronic Data Interchange (EDI)</td>
<td>48.9%</td>
<td>167</td>
<td>53.4%</td>
</tr>
</tbody>
</table>

---

**Preliminary Hypotheses Testing: Using Adopter Subsamples**

Treatment of nonadopters in the analysis of the hypotheses poses a problem, as very little is known about their innovativeness or their propensity to adopt after the date of the survey. The most common solution is to consider only adopters in the analysis. Alternatively, more robust treatment of nonadopters can be attempted with recent techniques developed in survival analysis. Both these analyses are presented below. The adopter-only analysis is presented first and discussed briefly. It represents raw correlations among the adopter subsamples. It is important to note, however, that survival analysis (presented later) is not only more sensitive to the detection of significance, but has both conceptual and methodological advantages.

To test for hypotheses related to the earliness of adoption, Pearson's zero-order correlations were computed between the number of years since first adoption of the innovation and the various variables involved. A statistically significant relationship (adjusting for the differences in sample size since only adopting subsamples were used for each innovation) indicates support for hypotheses related to earlier adopters. Table 3 presents the results of hypotheses testing.

In summary, the results provide strong support for the hypotheses in the case of IS and organizational size (H1a, b, c), technological diversity (H3a, b), and some support for professionalism (H4a) and strategic IS (H5). Virtually no support for the IS (H2a) and organizational slack (H2b, c) variables was found. The patterns of significant and nonsignificant results seem to provide evidence in favor of the model; 42% of expected and only 9% of the unexpected relationships were found.

The elimination of nonadopters from the above analysis makes the implicit assumption that if they are included (e.g., by waiting longer), they would have no effect on the results. Also, the potentially smaller variance and sample size of the adopter sample could understate the significance of results. Below, event history analysis is conducted in order to provide more sophisticated treatment of nonadopters. While this technique works best with adoption subsamples greater than 50%, it provides an alternative way to look at the data and can be used to improve on the above analysis to determine support for the model.

**Hypotheses Testing: Event History Analysis**

Event History Analysis (EHA), or survival analysis, is used by psychologists and epidemiologists to effectively study factors influencing events (e.g., death) that may or may not have occurred for all observations in the study. In doing so, it provides sophisticated treatment of "censored" cases (or nonadopters in this study). An excellent treatment of the topic can be found in Cox and Oakes (1984) and in Singer and Willett (1991). Appendix A summarizes salient aspects of the methodology as applied to this study.

To examine the effects of the independent variables (or covariates) on the survival function (or hazard function), Cox regression was used and Wald's statistic depicting the overall significance of the model was assessed. Eighty individual models were run, ten for each covariate. The results are summarized in Table.

---

2Each covariate was categorized into two or three categories, and an
Table 3  Testing the Hypotheses Using Adopter Subsamples

<table>
<thead>
<tr>
<th>Variable</th>
<th>Operationalization</th>
<th>Type 1 Innovation</th>
<th>Type 2 Innovation</th>
<th>Type 3 Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Outsourcing</td>
<td>CASE</td>
<td>OOPS</td>
</tr>
<tr>
<td>IS Size (H1a)</td>
<td>IS Budget</td>
<td>n.s.</td>
<td>0.32***</td>
<td>0.34***</td>
</tr>
<tr>
<td>Organizational Size (H1b, H1c)</td>
<td>Revenue ($)</td>
<td>n.s.</td>
<td>0.45***</td>
<td>n.s.</td>
</tr>
<tr>
<td># of Employees</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>IS Slack (H2a)</td>
<td>IS Budget/Sales</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Organizational Slack (H2b, H2c)</td>
<td>Profitability (multitem)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Technological Diversity (H3a, H3b)</td>
<td>Number of Different Technologies</td>
<td>n.s.</td>
<td>0.28***</td>
<td>n.s.</td>
</tr>
<tr>
<td>Professionalism (H4a, H4b)</td>
<td>Technology Scanning (multitem)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>0.23*</td>
</tr>
<tr>
<td>Strategic IS (H5)</td>
<td>Extent to which IS is Strategic</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>
to the Business (multitem)        | n.s.                             | n.s.              | n.s.              | n.s.              | n.s.              | n.s.  | n.s.              | n.s.          | n.s.   | n.s.   | n.s.  |

*P < 0.10; **P < 0.05; ***P < 0.01.

Hypothesized Relationships

As can be seen in Table 4, there is evidence supporting Hypothesis 1a. Three of the four technical process innovations (CASE, OOPS, and DBMS) exhibit strong relationships with IS size (H1a). The fourth one, outsourcing, does not. Outsourcing relates to a change in the governance mechanism and represents a distinct type of administrative process innovation. However, it is possible that the innovation itself might go beyond the change in governance mechanism to a transfer of control of the IS function. In such cases the notion of IS budget as an indicator of IS size might not be reflective of the innovation dynamic, as a portion of that budget is out of direct IS control. This might introduce "noise" in the results. Nevertheless, the strong relationships for three relatively unambiguous Type 1 innovations provide reasonably strong evidence for Hypothesis 1a.

Regarding Hypotheses 1b and 1c, organizational size (as measured by either revenue or employees) exhibits relationships with all the Type 2 and Type 3 innovations. This suggests that large (and presumably differentiated) organizations are early adopters of IS products in their administrative structure and core business. Collectively, hypotheses related to size are well supported.

Relationships for IS slack and Type 1 innovation have limited support (H2a). One of the four innovations—OOPS, arguably the most fundamental to the conduct of IS work—shows a significant relationship. Similarly, relationships between organizational slack and early adoption of Type 2 and Type 3 innovations (H2b and H2c) are not significant (with the exception of Expert Systems). The lack of strong support for Hypotheses 2 might be reflective of methodological issues

LML plot was examined for each category/technology combination (Norusis 1993). The lines for individual strata were clearly parallel in most cases. In cases involving the technological diversity variable there was a slight violation of the proportional hazards assumption.

Information Systems Research
Vol. 8, No. 3, September 1997

281
Table 4  Alternative Treatment of Nonadopters Using Cox’s Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Operationalization</th>
<th>Type 1 Innovation</th>
<th>Type 2 Innovation</th>
<th>Type 3 Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS Size (H1a)</td>
<td>IS Budget</td>
<td>n.s.</td>
<td>38.81***</td>
<td>21.14***</td>
</tr>
<tr>
<td>Organizational Size (H1b, H1c)</td>
<td>Revenue ($# of Employees)</td>
<td>n.s.</td>
<td>26.09***</td>
<td>21.08***</td>
</tr>
<tr>
<td>IS Slack (H2a)</td>
<td>IS Budget/Sales</td>
<td>n.s.</td>
<td>16.13***</td>
<td>n.s.</td>
</tr>
<tr>
<td>Organizational slack (H2b, H2c)</td>
<td>Profitability (multitem)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Technological Diversity (H3a, H3b)</td>
<td>Number of Different Technologies (H4a, H4b)</td>
<td>n.s.</td>
<td>60.87***</td>
<td>63.57***</td>
</tr>
<tr>
<td>Professionalism (H4a, H4b)</td>
<td>Technology Scanning (multitem)</td>
<td>n.s.</td>
<td>5.78***</td>
<td>5.78***</td>
</tr>
<tr>
<td>Strategic IS (H5)</td>
<td>Extent to which IS is strategic to the business (multitem)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

*P < 0.10; **P < 0.05; ***P < 0.01

Hypothesized Relationships

such as incomplete measurement of true organizational slack. For instance, IS budgets per unit sales might need to be normalized by industry. Also, satisfaction with profitability might not correspond to slack at a decentralized local level. It is also possible that the senior IS executive might be poorly informed about this construct. Or, these results might suggest the reduced importance of slack where much of the risk of technological fit is being absorbed by vendor organizations through diversification, packaging, and after-sales servicing of technological products.

Hypotheses 3, relating the earliness of adoption of Type 2 (H3a) and Type 3 (H3b) innovation to technological diversity, shows strong support. All six of the Type 2 and Type 3 technologies exhibit significant relationships with technological diversity. This indicates the importance of such diversity in promoting IS innovation in the host organization—beyond the confines of the IS function.

Hypotheses 4a and 4b, related to professionalism, have moderate overall support. Outsourcing, OOPS, teleconferencing, and expert systems are four of the eight innovations that showed significant (at p < 0.05) relationships with professionalism, perhaps reflecting the importance of technological proactiveness for these innovations which tend to have a professional infrastructure. However, the nonsignificant relationships with early adoption of other Type 1 and Type 2 innovations is rather surprising, since an organization’s tight affiliation with the technological environment should lead to innovations closer to the core IS function. Since interaction effects among variables were not examined, it is possible that domination of “business coupling” (or the affiliation of the IS function with the host organization rather than its professional environment) in most organizations would force an organizational imperative on the technologies, such as EIS and e-mail, and reduce the effects of professionalism.

Hypothesis 5, relating earliness of adoption of Type 3 innovation to the extent to which IS is strategic to the business, received some support in the case of EDI (p < 0.10). This might suggest that some strategic
imperatives for IS reach the core business elements directly rather than through weak order effects of Type 1 and Type 2 innovation. However, it is possible that certain Type 3 innovations are adopted by individual units in order to improve work processes rather than any global strategic imperative. This might reduce the effect of the strategic role of IS in the organization.

All 15 of the cells (hypotheses) that had significant results in the adopter-only analysis show significance in the EHA analysis. In addition, stronger support exists for some of the hypotheses. Hypothesis 1a shows DBMS adoption related to IS size, thereby providing support for three of four Type 1 innovations. Hypotheses 2a and 2b, which had no support in prior analysis, now have some support with relationships demonstrated between IS slack and OOPS, and between organizational slack and expert systems. Hypothesis 3a also shows stronger support with all six Type 2 and Type 3 innovations related to technological diversity. Finally, Hypotheses 4a and 4b had some further support showing relationships between professionalism and outsourcing, teleconferencing, and expert systems. In sum, not only does EHA have better sensitivity and a nonbiased inclusion of nonadopter in the analysis, it provides better support for the Swanson model, with 58% of the expected relationships supported.

Discussion of the Model

In assessing support for the overall model it is critical to examine the fundamental premise of Swanson's work, which is the importance of defining classes of innovations and developing a rationale for their separate treatment. This is very different from the typical approach of treating all IS innovations as being the same or having similar facilitators. The hypotheses reflect the distinction made in innovation types and are examined in light of limitations in analysis and design of the study.

Overall, the results demonstrate a pattern of significant effects that are consistent with the general thrust of Swanson's theory. In the adopter analysis 42% (15 of 36) of the expected and only 9% (3 of 34) of the unexpected relationships were observed. In the EHA analysis, an even higher proportion (58%, or 21/36) of the expected and 9/34 (26%) of the unexpected relationships were observed. The difference in both cases is noteworthy and provides evidence for the particular pattern of relationships suggested by the theory.

Despite the encouraging results, it is important to note that this study was conducted in a retrospective mode based on a single respondent per organization. As such, it has feedback problems and method bias that characterize much of the innovation work. For instance, hypotheses related to earliness of adoption are tested using respondent's assessment of variables. With the exception of DBMS and Expert systems, all IS innovations studied spanned a period of about 10 years, with the majority more recent than that. Relative invariance is assumed on the part of variables such as size, slack, etc. over this period. Ideally, this testing should be done longitudinally, with assessment of variables at the time of first adoption. However, the difficulty in doing such research, the preliminary nature of this study, and the recency of most innovations investigated led to the selection of this approach. We would argue, however, that any inaccuracy in response that introduces noise in the assessment of variables and adoption dates by the respondent would decrease the strength of the observed relationship. On compression of the years since adoption scale (by using a square root transformation), the results obtained were stable, thereby, de-emphasizing the importance of precision in assessing the year of adoption.

Finally, the issue of variable measurement is of some concern in light of the results. IS slack (as measured by IS Budget/Sales) and Organizational Slack (measured by satisfaction with profitability) demonstrated weak results. This might be due to the fact that these variables do not fully capture the notion of "slack." For instance IS Budget/Sales may include IS resource budgets that are not under control of the professional IS core. This could overstate the IS budget in some cases, adding noise to the results. Also, by mixing industries for this variable, high ratios could potentially represent low slack, given the industry environment, further confounding the results. Satisfaction with profitability has the basic problem of having a single respondent perceive a macro-variable, and the additional problem that slack at the corporate level does not always translate to slack at the local level. If we eliminate these two variables, the EHA provides support for 20/26 (77%) of the remaining hypothesized relationships.
Another debatable point relates to the hypotheses on the diversity of technology. Swanson argues that innovative organizations are those that have a large, new, and diverse application system portfolio and work technologies. While such a portfolio may facilitate innovation in the administrative and business cores, it might require the IS group to find innovative ways to manage these newer technologies, and their collective consideration as an organizational resource. Therefore, it could be argued that these "strong order effects" could facilitate Type 1 innovation. This was not hypothesized. The EHA results, however, point to a strong relationship between technological diversity and three of the four Type 1 innovations.

In sum, we would argue that despite these issues, the support for Swanson's theory exceeds any data pattern that could be obtained by chance.

Further Research Directions
Based on these results, we conclude that the tri-core model is an appropriate starting point for structuring IS innovation work. Future work should continue to validate and refine the model. Further evidence with improved methodology of differences in IS innovations, and the presence of weak and strong order effects, will serve to bridge the gap between IS innovation and the larger organizational context. Also, the theory can be generalized to study the development and diffusion of innovation within other specialized subunits and the organization.

In more specific terms, the data provide evidence supporting the most fundamental premise of the Swanson model, the differential contingencies for IS innovation across the proposed typology. However, while the results provide a unique pattern that is difficult to explain by chance (despite methodological limitations outlined above), they do not represent overwhelming support for the model. We believe that clear demarcation of antecedents between Type 1, 2, and 3 innovations can be blurred by three factors. While we do not have evidence on any of the caveats presented below, they can provide rich avenues for future research aimed at refinement or expansion of the model.

The first caveat resides in the domain of strategy and/or directive. The current model grows from its origin in the innovation dynamic. The innovation dynamic presumes that IS innovation stems from size, diversity, flexibility and integration, all characteristics of organic structures. Such structures presume that uncertainty is the major source of creativity in the organization, and that institutional leadership is critical in creating a context that fosters innovation. These characteristics, as discussed by Swanson, are reinforced by the professional affiliation present in the IS functional core and business or strategic rationales, as we move toward the administrative and technical core of the host organization. In other words, core process technology (like CAD/CAM) would have a more immediate relationship with the factors associated with the innovation dynamic at the organizational level and the business orientation of the host organization (particularly when IS is recognized as strategic). On the other hand, core IS technology (like OOPs) would have a more immediate relationship with factors associated with the innovation dynamic at the unit level as well as the professional orientation of the IS unit. These distinctions, however, might be indistinguishable in cases where organizational strategy or directive mandates a Type 1, 2, or 3 innovation. Alternatively stated, cycles of strong order effect (triggered by business needs, environmental pressure, etc.) may be dramatically compressed in cases where a Type 3 innovation requires rapid innovation in the inner cores.

As discussed by Van De Ven (1986), "managing diversity requires framing ideas and problems so that they can be approached through experimentation and selection. [In contrast] order results from imposing standards and a concept of strategy on the organization" (p. 603). The latter is particularly true in cases where organizational directives or mandates predominate, causing rapid intervention, structural changes, and innovation at all levels. Such organizational imperatives, which are reflective of the intent of the organization and its decision makers, can affect various facets of the tri-core model. Study of strategy content and directives as factors moderating the relationship between antecedents and innovation in each group might be a fruitful avenue for exploring any noise in the current model.

A second related caveat is the nature of information
technology itself. There are a large number of complex technologies being introduced, and the interrelationships between these technologies are increasing. While IT by itself is neutral, the scope of impact could differ across technologies. Some technologies relate to individuals or groups while others are inherently infrastructural (e.g., organizational networks). These infrastructural technologies by their inherent nature can facilitate organizational integration, require widespread participation (i.e., a critical mass) in order to be effective, and can often be applied to change the fundamental nature of a business process, usually transcending the various cores discussed by Swanson. For instance, adoption of a TCP/IP based "Intranet" could directly enable object oriented application development (Type 1 innovation), electronic mail systems (Type 2), and proprietary links to customers using firewalls (Type 3). As such, the factors involved in their adoption might be different, involving aspects of the innovation dynamic, strategy, and other considerations such as organizational infrastructure and integrative needs. Such infrastructural technologies (e.g., platforms on which e-mail, teleconferencing, etc. are built) might be worthy of future study, perhaps as a fourth category of IS innovation types, with antecedents that span all the cores.

Finally, with the substantial recent interest in business process reengineering, many organizations are restructuring their interfunctional processes. Rapid and substantial IS innovation is occurring as a strategy initiated imperative involving integrative information technologies, often with a cost motif of leveraging investments in information technology (Grover et al. 1994). The innovation dynamic implicit in the Swanson model (and in much of the prior innovation work) needs to be tested in these contexts. Further, in order to complement this model and evolve toward a more holistic and integrative theory of organizational innovation, substantive concepts from innovation, organizational learning (Argyris and Schon 1978) strategic management, and organizational change (Lant and Mezias 1992) need to be contrasted, tested, and structured. For instance, further examination of innovation-decision predictors, particularly those that are context dependent (e.g., compatibility), is warranted (Meyer and Goes 1988). Another avenue is to reexamine the origins of the dual-core model, which was based on socio-technical change theory (Passmore et al. 1982), and integrate it with innovation theory. Another is to examine taxonomies proposed in reengineering as they relate to the model. For instance, Venkatraman's (1991) five levels of process redesign (local, infrastructural, process, scope, network) might exhibit parallels with movement from the inner core to the business core of the model.

Conclusion

Existing studies on IS innovation typically examine single innovations in isolation and do not effectively integrate notions of IS innovation with organizational innovation. The Swanson model challenges the assumption of homogeneity across IS innovations and provides a useful typology that transcends the organization and can form the foundation for innovation theory in this important area. More importantly, the results of this study, performed using large sample, cross-sectional data and sophisticated treatment of nonadopters, allow us to conclude on a note of cautious optimism regarding Swanson's work.

We would suggest that while there is room and need for further theoretical refinement, elaboration, and extension of the model, the pattern of results indicates that there are systemic differences in IS innovation types. If this is confirmed in future study, then its implications can lead to a better evaluation of the context-IS innovation-outcome relationship. Certain types of IS innovations can be nurtured by providing the appropriate organizational context (i.e., slack, business versus professional coupling, technological diversity, etc.). The evolution of IS innovations, where one type spawns another through strong and weak order effects, can form a basis for the management of IS innovation. And, the differential contingencies for diffusion of the three types of innovations specifically address the distinctions between innovations that are close to the IS core, and those that are inextricably intertwined with organizational innovation.

In conclusion, the results of this study provide support for hypotheses related to Swanson's model, indicating both its viability as an integrating framework in this area and the importance of continued research in
this direction. Further research should test and refine this model, and include notions of strong and weak order effects. Ideally, such study should be done longitudinally—which means that researchers might want to explore interventions in the model through qualitative small sample study methods.

The authors would like to thank the Associate Editor, the anonymous referees, and John King for their constructive comments on the manuscript. Funding for this research was provided by the Center for International Business Education and Research at the University of South Carolina, through a grant from the United States Department of Education.

Appendix A  Brief Description of EHA
Event History Analysis (EHA) or Survival Analysis addresses the fundamental problem of how to handle “censored” observations, or observations for which a target event does not occur by the time data collection ends. Censoring complicates research design and analysis. For instance, in this study “adoption” of a particular IS innovation is the event, and for each innovation a significant proportion of the sample has not adopted the innovation or incurred the event. The most common strategy among researchers to deal with the dilemma of censored observations is to ignore them, in other words, to restrict data analysis (and even data collection) to uncensored observations. Of course by doing this (e.g., considering only adopters), there is an assumption of invariance of results introduced or in other words, if the nonadopters could somehow be included (i.e., by waiting longer), the results would not change.

Recently, new methods—known as EHA, survival analysis, or hazards modeling—have been developed by biostatisticians modeling human lifetimes (Cox and Oakes 1984). These methods help researchers better study whether events occur and the factors influencing their occurrence. While the genesis of these methods is in modeling human lifetimes (where the event is death), the techniques provide a way of using all observations in a study (censored and uncensored). While an excellent and detailed treatment of survival analysis can be found in Singer and Willett (1991), below a few of the salient concepts related to this study are emphasized.

Survival analysis begins with the survival function. This function represents the probability over time of the observation “surviving” (or not adopting the innovation). For each innovation, a survival function will represent the probability of nonadoption, from the time of first adoption to the time of last adoption. At the beginning of the function the probability is 1, and at the end it represents the proportion that did not adopt. Because of censoring (nonadoption), survival functions do not reach 0. Sharp downward slopes in the survival function over a time period indicate that there is a greater “risk” of an organization adopting an innovation (or not surviving) over that period. An alternative function called the hazard function is used to describe this risk. The hazard function represents the conditional probability that an organization will adopt in a particular time period, given that the organization has not adopted by the beginning of the period. For instance, if an organization has not adopted CASE technology for five years since it first appeared in the market, the hazard function represents the conditional probability of adoption in year six.

The Cox regression model allows a comparison of survival (or hazard) functions, based on different values of independent (or predictor) variables called covariates. A cumulative survival function with one covariate \( X \) can be represented as:

\[
S(t) = [S_0(t)]^e \quad \text{where } p = e^{bX}.
\]

\( S(t) \) is the proportion of cases surviving at point \( t \), \( S_0(t) \) is the baseline survival function, and \( b \) is the regression coefficient. In our study, the survival function indicates the proportion of cases not adopting by a particular year, and individual regressions are run for each covariate (IS budget, organizational size, slack, etc.). The hazard function (derived from the survival function) can be written as:

\[
h(t) = [S_0(t)]e^{bX}.
\]

One of the assumptions of the Cox regression model is the “proportional hazards” assumption. This assumes that the baseline function is invariant or that the ratio of two hazard functions is constant across time (regardless of the level of the covariate). This may or may not be true. For instance, will companies with high levels of professionalism and low levels of professionalism have comparable hazard functions for the adoption of CASE over time? It is possible that high professionalism might be unduly more important to adoption during the early years of CASE technology existence. This assumption can be checked using the log-minus-log (LML) survival plot.

Cox regressions produce statistics similar to those in linear regression. The coefficient \( B \) is tested by using the t-test. Coefficients are also tested using the Wald statistic (analogous to \( F \) in regression). This statistic is the ratio of the coefficient \( B \) to its standard error. Under the null hypothesis that the coefficient is 0, it follows a Chi-Square distribution (with 1 df).

References


Michael Vitale, Associate Editor. This paper was received on July 6, 1995, and has been with the authors 9 months for 3 revisions.