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Research Report: Diffusion of Information Systems Outsourcing: A Reevaluation of Influence Sources

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Information systems outsourcing is an increasingly popular IS management practice in companies of all sizes. Examining the adoption of IS outsourcing from the well-developed theoretical foundation of innovation diffusion may shed some light on significant factors that affect the adoption decision, and clarify some misperceptions. This study explores the sources of influence in the adoption of IS outsourcing. Using a sample of 175 firms that outsourced their IS functions during the period from January 1985 to January 1995, we tested three hypotheses of sources of influences using four diffusion models: internal influence, external influence, and two mixed influence models. Our findings suggest that the mixed influence is the dominant influence factor in the diffusion of IS outsourcing, and that there is no evidence of the "Kodak effect" in the IS diffusion process. This directly contradicts the conclusions of the Loh and Venkatraman (1992) study. Further discussions are provided about the potential problems in studies of influence sources of IT innovation diffusion.
(*Information System Outsourcing; Innovation Diffusion*)

1. Introduction

Information systems (IS) outsourcing is an increasingly common business practice in which a company contracts all or part of its information systems operations to one or more outside information service suppliers. This is done to acquire economic, technological, and strategic advantages. Over the last decade, information systems outsourcing has gained increasing popularity in companies of all sizes. In the United States alone, approximately $25 billion was spent on outsourcing in 1989 (Livingston 1990) and $30 billion in 1990 (Huff 1991). An estimate by the Yankee Group places the 1994 IS outsourcing market at $50 billion, with an annual growth rate of 15% (Patane and Jurison 1994).

Outsourcing is a practical issue that also has significant impact on business organization theories. It has, therefore, drawn a great deal of attention from both practitioners and researchers. In a recent survey, senior IS executives rated acquiring outside services as one of the six most important strategic issues confronting their organizations (Clark 1992). Despite the stated interest and wide press coverage, there are still many unanswered fundamental questions. Among these is the identification of the sources of influence in the adoption decision. Is information systems outsourcing motivated primarily by internal or by external influences? That is, do organizations imitate the behavior of other organizations in the same social system that

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have adopted outsourcing, or are they motivated primarily by such external influences as mass media reports and vendor sales pitches?

Understanding the exact nature of influence sources of the adoption of information systems outsourcing practice has significant organizational and managerial implications. Management interest in these implications is not surprising given the size of the economic commitment reflected in the outsourcing agreements and the ability of the agreements to change the mode of governance of information technology from within the hierarchy to hybrid modes involving external companies. As the importance of outsourcing agreements increases, it becomes important to understand the sources that influence the decision in order to ensure that an accurate picture of the arrangement and its consequences are presented and considered in making this decision.

External influence in the IS outsourcing decision has been exerted aggressively on managers by vendors in recent years. These same managers have been barraged by the extensive coverage of the outsourcing phenomenon in the trade press. Another source, an internal influence source, has been the communications among the managers whose companies have outsourced their IS function, or who have decided against IS outsourcing. These communication sources have all been identified in the Lacity and Hirschheim (1993) study. But the question remains: which source, if any, plays a more significant role in influencing the decision to adopt IS outsourcing? Loh and Venkatraman (1992) have argued that, as important as the trade press and vendors may be in influencing managers to adopt IS outsourcing, decision makers are primarily swayed by the communications among the computer-user organizations that may be considering, or have adopted, IS outsourcing.

Loh and Venkatraman (1992) further suggest that the importance of internal influences, or sources at other organizations considering IS outsourcing, became even more pronounced after July, 1989, when Kodak announced a unique contract in which data center operations were outsourced to IBM and two other vendors. They argue that the announcement of this agreement is a watershed event. Kodak became an opinion leader, and its decision to outsource influenced other companies to make a similar decision. After the Kodak decision, but not before, managers in companies considering IS outsourcing received their information about these arrangements from individuals in other companies. This "Kodak effect" occurred because of the prominence of the two companies involved (i.e., Kodak and IBM), the size of the contract ($500 million), and the impetus it provided other managers to consider outsourcing as a governance option. Loh and Venkatraman (1992) argue that the Kodak event significantly differentiates the pattern of influences in the diffusion of IS outsourcing.

The Loh and Venkatraman (1992) study has been widely cited in subsequent studies of outsourcing arrangements. The Social Sciences Citation Index (1992–1996) lists 13 publications that have cited the Loh and Venkatraman (1992) study, and there are numerous other citations in conference papers and books. We argue in this paper that while the Loh and Venkatraman study has made a contribution to research on the influence sources of IT innovation diffusion, its problematic data errors and methodological flaws cast serious doubt on the findings about the characteristics of the IT innovation diffusion processes.

Our study, described in this paper, explores influence sources in the adoption of IS outsourcing innovation. Using a sample of 175 firms that outsourced during the period from January 1985 to January 1995, we test three hypotheses of influence sources using four diffusion models: internal influence, external influence, and two mixed influence models. We also reexamine Loh and Venkatraman (1992) study with expanded data set and model set to see if their conclusions about the influence sources can be substantiated with the larger data set and if any significant changes have occurred in terms of the characteristics of IS outsourcing diffusion since the publication of their study.

2. Studies of Innovation Diffusion

Innovation diffusion is defined as the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers 1983). Thus, four key elements determine the characteristics of the diffusion process of an innovation: innovation, time, social system, and communication channels. According to Rogers (1983), an innovation is "any idea, object, or practice that is perceived as new by the members of a social systems . . . Time relates to the rate at which the innovation is diffused or the relative speed with which it is adopted by members of the social system . . . [T]he social system consists of individuals, organizations, or agencies that share a common 'culture' and are potential adopters of the innovation . . . Communication channels are the means by which information is transmitted to or within the social system" (p. 5). Communication channels have a significant effect on how the diffusion develops and matures. Researchers have categorized communication channels as either interpersonal or mass media. Interpersonal communication channels employ a face-to-face exchange between two or more individuals in the social system. In contrast, mass media channels transmit an innovation to members of a social system via the radio, television, newspapers, or other such channels which enable a source of one or a few members of a social system to reach an audience of many (Rogers 1983).

Traditionally, innovation diffusion research centers around these four areas discussed above and their interrelationships. A rich body of studies (see Mahajan and Peterson 1985) has focused on the relationship between the time element of a diffusion process and communication channels. From these studies have emerged well-defined mathematical models of diffusion that allow quantitative examination of diffusion processes. These models describe the level or spread of an innovation among a given set of prospective adopters in a social system at any given time since the introduction of an innovation. Such models, if properly developed and tested, permit the prediction of the continued development of the diffusion processes over time and the theoretical explanations of their dynamics. The following section briefly describes four diffusion models based mostly on the work of Mahajan and Peterson (1985). For comparison purposes, a white noise diffusion model is also presented.

2.1. Diffusion Models

In the fundamental diffusion models, the rate of diffusion is proportional to the potential number of adopters at a given time, calibrated by the diffusion coefficient which, in general, is a function of time. This type of model usually gives an S-shaped diffusion curve of cumulative number of adopters as a function of time. It may be represented as follows: Given an innovation that has been introduced to a social system at time $T = 0$, let m be the potential number of adopters of this innovation at time $T = t$, and $N(t)$ be the number of adopters at $T = t$. Then, in general, the rate of diffusion of this innovation in this social system can be described as the first order derivative of $N(t)$ with respect to t, and can be defined as

$$\frac{dN(t)}{dt} = g(t)(m - N(t)), \tag{1}$$

where $g(t)$ is the coefficient of diffusion.

At the beginning of the diffusion, m and $N(t)$ are both small, so the rate is low, and $N(t)$ grows slowly. Gradually, with the help of communication channels, m increases significantly, resulting in a higher diffusion rate and fast growth of $N(t)$. Eventually, m reaches its peak, and $N(t)$ continues to grow, resulting in a decreased diffusion rate and a slowed growth of $N(t)$. This results in an S-shaped curve.

Mahajan and Peterson (1985) presented three fundamental diffusion models: internal, external, and mixed. Different assumptions about the characteristics of communications channels, or influence sources as they are often called, distinguish these fundamental diffusion models. The different model assumptions are described in the following sections.

2.1.1. The Internal Influence Model. The internal influence model assumes that the communication channels of an innovation in a social system are interpersonal: the adopters ($N(t)$) communicate face-to-face with potential adopters (m). Thus $g(t)$ is directly proportional to the number of adopters, let $g(t) = qN(t)$, where $q > 0$ is the internal coefficient of diffusion. Substituting it into the fundamental diffusion model (1) yields

$$\frac{dN(t)}{dt} = qN(t)(m - N(t)). \tag{2}$$

Integrating Equation (2) with respect to t in the time period [0, t], we obtain the cumulative form of the internal influence model

$$N(t) = \frac{m}{1 + \frac{m - m_0}{m_0}\exp(-qmt)}, \qquad (3)$$

where m_0 is the number of adopters of the innovation at $T = 0$. The parameters of this model can be estimated by using the time series data of cumulative number of adopters of a specific innovation in a given social system.

2.1.2. The External Influence Model. Obviously there are plenty of situations in which the use of interpersonal communication channels may not be applicable or realistic. In those cases, mass media are considered as the main, if not sole, communication channels of a diffusion. Under this assumption, $g(t) = p$, where $p > 0$ is the external coefficient of diffusion. Substituting g(t) into the fundamental diffusion model (1) yields

$$\frac{dN(t)}{dt} = p(m - N(t)). \qquad (4)$$

This is called the external influence model of diffusion. Integrating Equation (3) with respect to t in the time period [0, t] yields

$$N(t) = m(1 - \exp(-pt)). \qquad (5)$$

With its simple structure, the external influence model can be easily estimated using time series data of the cumulative number of adopters of a specific innovation in a given social system.

2.1.3. The Mixed Influence Model. Although numerous studies have shown that certain innovations may indeed be communicated through either the interpersonal or the mass media channels (Mahajan and Peterson 1985), it is only logical to expect that in certain social systems, a specific innovation is communicated among the members of that social system via both interpersonal and mass media channels. This creates a new influence model which is the combination of the internal and external models, defined as

$$\frac{dN(t)}{dt} = (p + qN(t))(m - N(t)). \qquad (6)$$

This model is called the mixed influence model of diffusion. Integrating Equation (5) with respect to t in the time period [0, t] yields

$$N(t) = \frac{m - \frac{p(m - m_0)}{p + qm_0}\exp(-(p + qm)t)}{1 + \frac{q(m - m_0)}{p + qm_0}\exp(-(p + qm)t)}. \qquad (7)$$

This mixed influence model has a more complex mathematical structure than the internal and external models. But with current statistical software packages, it is not difficult to directly estimate the parameters from the time series data of cumulative adopters of a specific innovation in a given social system, thus making it a useful addition to the diffusion model family.

2.1.4. The Von Bertalanffy Model. The diffusion models presented so far, though very different in terms of structure and meaning, have one common feature: they belong to the so-called inflexible diffusion model family. This is because their point of inflection, at which the diffusion rate reaches the maximum and the second order derivative of the $N(t)$ changes sign, must occur when 50% or fewer of the potential adopters have adopted the innovation. Such limitation may be unwarranted for certain innovation diffusion processes in a given social system. Von Bertalanffy (1957) introduced a diffusion model that has a flexible inflection point. Here we use the Mahajan and Peterson (1985) formulation of this model in order to be comparable with others. It is defined as

$$\frac{dN(t)}{dt} = \frac{b}{1 - \theta}N^{\theta}(t)(m^{1-\theta} - N^{1-\theta}(t)), \qquad (8)$$

where $b > 0$ and $\theta > 0$ are model parameters that determine the characteristics of this model. It can be seen that when $\theta = 0$, Equation (8) reduces to the external influence model (4); when $\theta = 2$, Equation (8) reduces to the internal influence model (2) with $q = b/m$; and when $\theta \Rightarrow 1$ Equation (8) reduces to the Gompertz internal influence model (Mahajan and Peterson 1985). When θ takes on any other value, it defines a diffusion process with mixed influences.

Integrating Equation (8) with respect to t in the time period [0, t] yields

$$N(t) = (m^{1-\theta} - (m^{1-\theta} - m_0^{1-\theta})\exp(-bt))^{1/(1-\theta)}. \qquad (9)$$

This model has several unique characteristics that are important to this study. First, unlike the fundamental mixed influence model, it is not a nested version of the fundamental internal, external, and mixed models, meaning that it cannot be derived simply by eliminating variables in the three fundamental models, or vice versa. This allows us to test it directly against the three fundamental models using the advanced statistical procedures introduced later. Second, it has a flexible inflection point and is asymmetric around this point, which means it can accommodate the situations in which the maximum diffusion rate may occur at any time in the entire diffusion spectrum. And finally, even though it is a mixed influence model by definition, values of its parameters allow it to become either internal or external models. This is particularly valuable when little is known about the diffusion of an innovation under study.

2.1.5. The White Noise Model. The study of innovation diffusion, by its very definition, deals with new phenomena. Thus, it is associated with the inevitable uncertainty as to whether a diffusion process follows any specific pattern at all. Conventionally a white noise model of diffusion is used as the null hypothesis that the diffusion of the innovation under examination simply follows a random walk. This white noise model can be defined as (Mahajan et al. 1988)

$$x(t) = x(t - 1) + \varepsilon(t), \tag{10}$$

where $x(t)$ is the number of adopters at time period t, and $x(t - 1)$ is the number of adopters at the time period $(t - 1)$, and $\varepsilon(t)$ is the random error with normal distribution $N(0, \sigma_\varepsilon^2)$.

The white noise model defined in (10) represents a diffusion time series. In order to test this null model against the four cumulative diffusion models discussed before, we modify the time series specification into a cumulative white noise model specification:

$$N(t) = N(t - 1) + \varepsilon(t), \tag{11}$$

where $N(t)$ is the total number of adopters of an innovation at time t, and $N(t - 1)$ is the total number of adopters at time $(t - 1)$, and $\varepsilon(t)$ is the random error with normal distribution $N(0, \sigma_\varepsilon^2)$.

As can be seen, the white noise model is introduced for the purpose of testing the strength of other models. In a pairwise comparative test, if a proposed diffusion model could not even reject the white noise model, then there is no need to proceed further. This leads to a more fundamental question: how to fairly and accurately evaluate alternative and competing models for the same phenomenon?

2.2. Evaluation of Competing Models

Choosing from competing alternative models of the same social or economic phenomenon has been a difficult issue facing researchers for many years. The traditional methods of testing for the goodness of fit have been shown ineffective in many circumstances (Pesaran 1974, Matson et al. 1994). The need for better statistical procedures and methods for testing alternative models has prompted a series of studies since early 1960s (Cox 1962, Atkinson 1970, Pesaran 1974, Pesaran and Deaton 1978, Davidson and MacKinnon 1981). The tests developed by Davidson and MacKinnon (1981) have attracted much attention for their power and mathematical parsimony. The two most important tests in the Davidson and MacKinnon test family are the J-test and P-test. These two tests were designed to test the specification of an econometric model in the presence of one or more alternative models which purport to explain the same phenomenon.

Suppose we want to test the truth of

$$H_0\colon y_i = f_i(X_i, \beta) + \varepsilon_{0i}, \tag{12}$$

where y_i is the ith observation of the dependent variable, X_i is a vector of observations of the independent variables, β is a k vector of the parameters to be estimated, and the error term ε_{0i} is assumed to be $N(0, \sigma_\varepsilon^2)$.

Suppose that there is an alternative model

$$H_1\colon y_i = g_i(Z_i, \gamma) + \varepsilon_{1i}, \tag{13}$$

where Z_i is a vector of observations of the independent variables, γ is an l vector of the parameters to be estimated, and the error term ε_{1i} is assumed to be $N(0, \sigma_\varepsilon^2)$.

If the null model H_0 is linear, Davidson and MacKinnon (1981) proved that the following simple linear regression can be used to determine the truth of H_0 in the presence of an alternative H_1:

$$y_i - \hat{f}_i = \alpha(\hat{g}_i - \hat{f}_i) + \varepsilon_i, \tag{14}$$

where $\hat{f}_i = f(X_i, \hat{\beta})$ and $\hat{g} = g(Z, \hat{\gamma})$ are the estimated values of the ith observation of dependent variable by the two competing models; y_i is the value of the ith observation of the dependent variable; and ϵ is the error term, assumed to be normally distributed $N(0, \sigma_\epsilon^2)$.

This test is called the J-test. It is especially useful when testing a linear null model such as the white noise model. If the null model H_0 is nonlinear, then a different test, called the P-test, should be used for determining the truth of H_0 in the presence of an alternative model H_1:

$$y_i - \hat{f}_i = \alpha(\hat{g}_i - \hat{f}_i) + \hat{F}_i b + \varepsilon_i, \qquad (15)$$

where $\hat{F}_i$ is a row vector containing the derivatives of f with respect to the parameters in β for the ith observation, evaluated at $\hat{\beta}$; α is the regression coefficient; and b is a vector of the regression coefficients of regressors in $\hat{F}$, (Davidson 1995). The rest of notations are the same as in the J-test.

Using the t-statistics of these two linear regressions, the decision regarding the truth of the null model can be made fairly easily: if α is statistically no different from zero, then H_0 is the true model; otherwise H_0 should be rejected. However, the rejection of H_0 does not necessarily imply the acceptance of H_1. To test whether H_1 is the true model, it has to be used as H_0 and tested against other alternatives as H_1.

2.3. Some Problems in the IT Innovation Studies

In recent years, there has been a surge of interest in applying the concept and research methodology of innovation diffusion to the study of IS innovations (e.g., Zmud 1982, Nilakanta and Scamell 1990, Brancheau and Wetherbe 1990, Cooper and Zmud 1990, Gurbaxani and Mendelson 1990, Loh and Venkatraman 1992, Prekumar et al. 1994, Straub 1994, Venkatraman et al. 1994, Kauffman and Wang 1994). Among these, the Loh and Venkatraman (1992) study is perhaps the first to use innovation diffusion theory to analyze the diffusion of IS outsourcing. After testing the three fundamental diffusion models against each other, using the P-test developed by Davidson and MacKinnon (1981), they concluded that the adoption of IS outsourcing is mainly motivated by internal influences. They also found that internal influences dominate in the post-Kodak, but not in the pre-Kodak regime.

However, significant problems have been overlooked in the Loh and Venkatraman (1992) (referred to hereafter as LV92) study. Given the potential influence of the publication on the future studies of IT innovation diffusion, we think it is important to identify these problems so that they can be avoided and corrected in future studies.

One major problem concerns estimated parameters. When the estimated parameters (m and p in Tables 2(a), 3(a), and 4(a) of LV92) are entered into the diffusion models (Equation (5) or (6), LV92, p. 345), no matter what the m_0 value is[1] ($0 < m_0 < m$ by definition), $N(t)$ (the number of outsourcing adopters at time (t)) calculated from the diffusion model varies little as the time period increases. $N(t)$ is always close to m, for all t ($t \geq 1$). This is a clear indication that the model parameters for the internal influence model are not properly estimated.

Furthermore, the description of the parameter B in LV92 Equation (11) (p. 346), reproduced here as Equation (16), is inconsistent with the original specification of the P-test as described in Davidson and MacKinnon (1981):

$$x(t) = (1 - \alpha)f(t) + \alpha\hat{g}(t) + \hat{F}\hat{B} + u(t). \qquad (16)$$

Their $\hat{B}$ should correspond to b in Equation (15) of Davidson and MacKinnon. However, the parameter b is a column vector of the regression coefficients of the regressors (Davidson 1995), rather than a vector of estimated parameters, as implied in LV(92). This change of specification changes the P-test from a multivariate linear regression into two variables, or possibly one variable, based on how the FB term is treated in the linear regression. No proof is provided to show whether such modification of the original P-test is valid. Since Equation (16) is the foundation of the P-test of LV92, this deviation may significantly affect the results.

In addition to these errors we believe that the LV92 study can be improved in three ways. First, although the use of the fundamental internal, external, and mixed diffusion models in the LV92 study provides

[1]LV92 did not report the estimated m_0 parameter (the initial number of adopters of IS outsourcing) for the internal influence models in their paper.

conceptual simplicity and mathematical parsimony, structural flexibility may have been sacrificed. Structural flexibility is critical when little is known about the characteristics of the diffusion of IS outsourcing. Adding the flexible diffusion models to the tests may shed more insight into the characteristics of the IS outsourcing diffusion.

Second, the conclusion that IS outsourcing is mainly motivated by internal influence among the members of a social system (i.e., business organizations of the same industry) through direct interpersonal contacts (the basic assumption of the internal influence model) is somewhat counterintuitive given the fact that LV92 acquired all their data about IS outsourcing contracts from two databases of major newspaper and trade magazines. This at least indicates the existence of the impact of mass media on the members of the IS community. In fact, the significant effects of the media, outsourcing vendors, and other social factors (e.g., economic conditions, technological changes) on the outsourcing decision have been well documented in the IS outsourcing literature. In analyzing how companies initiated the process of evaluating IS outsourcing, Lacity and Hirschheim (1993) identified the reaction to public outsourcing reports as one of the major motivators. Here is an example of what one decision maker was thinking when he initiated the process (Lacity and Hirschheim 1993):

> "You know, pick up one of these free rags that we get a dozen every week, you know outsourcing has been a popular topic. Spring of last year, about a year ago, I decided to talk to a few vendors and see if it really was cheaper to do it someplace else." (p. 216).

Certainly there are examples of internal influence as the major factor of initiating the evaluation of IS outsourcing. Once again from Lacity and Hirschheim (1993):

> "Two years ago I went to a National Coal Association Conference. I was talking to some of my peers in the industry. We were talking about data processing costs, comparing notes. I was amazed what this other company's costs were. They were so much cheaper than ours and they were approximately the same size company as us. So, I asked him, 'What is your secret?' He said, 'We outsourced.' " (p. 217).

These examples, at a minimum, support the existence of the combined effect of both internal and external influences in the decision of adoption of IS outsourcing practice.

Third, previous studies on innovation diffusion have shown that the assumptions of either the external or internal influence models can seldom be met unequivocally when investigating a diffusion process (Mahajan and Peterson 1985). For example, the external influence model assumes that there is no interaction between prior adopters and potential adopters. Moreover, the internal influence model assumes that the social system is relatively small and homogeneous. Due to the strict assumptions of the internal and external influence models, the mixed influence model is typically more appropriate, and more widely used, because it can accommodate the assumptions of these other two models. Given the errors in the LV92 study, it is highly likely that the significance of the mixed influence model has been erroneously reduced.

3. Research Hypotheses

The discussion presented above demands a rigorous reexamination of the previous studies and their conclusions on the diffusion of IT innovations. In the following sections, we focus on the main conclusions of the LV92 study: (1) internal influence is the dominant source of influence in the IS outsourcing decision, and (2) there is a Kodak effect in the diffusion of IS outsourcing. Since the assumptions of the internal and external influence models are more restrictive than the mixed models, we propose the following hypothesis about the influence sources of the adoption of IS outsourcing by organizations:

HYPOTHESIS I. *The decision to outsource IS is influenced by both internal and external sources. The mixed diffusion models should give the best results when used to describe the diffusion process of IS outsourcing.*

There are two types of mixed influence models: (1) fixed inflection point symmetric models, and (2) flexible inflection point asymmetric models (Mahajan and Peterson 1985). Theoretically, flexible models should do better than fixed models because of their adaptability to different situations. Therefore we propose the following hypothesis:

HYPOTHESIS II. *Diffusion models with a flexible inflection point should be at least as accurate as models with a fixed inflection point because there is no theoretical or empirical basis to support the assumption of a fixed inflection in the diffusion of IS outsourcing.*

Based on their analysis of outsourcing contracts obtained from a comprehensive bibliographic search, LV92 coined the term "Kodak effect." They suggested that one of the watershed events in IS outsourcing was the decision by Kodak to outsource many of its IS activities. LV92 argue that Kodak's highly publicized decision to outsource its IS is the point at which the internal influence model became dominant. The internal influences became the major driving force in outsourcing decisions only after Kodak announced its decision to outsource. However, this flow of logic is hard to follow. Prior to Kodak, with few companies outsourcing, and little media attention to speak of, it was likely that a firm's only chance to hear about outsourcing was through internal influences or direct contacts, e.g. chance meetings at conferences. The Post-Kodak information could come from either external or internal sources. This leads us to propose:

HYPOTHESIS III. *The internal influence model, i.e., direct personal communications among the members of a social system, dominates IS outsourcing diffusion in the pre-Kodak era, and the mixed influence model dominates IS outsourcing diffusion in the post-Kodak era.*

Certainly there is always the possibility that the diffusion of IS outsourcing does not follow any known pattern, or it is simply random. In the following sections, we conduct the comparative tests of the five diffusion models presented before using the J-test and P-test procedures to determine which hypotheses, if any, are supported by the observation of the IS outsourcing diffusion in the companies reported in the American press.

4. Data and Methods

4.1. Data

We supplemented LV92 data set by following similar methodology as described in LV92. To identify the companies that have outsourced their information systems, and the approximate dates when the outsourcing contracts were signed, we searched three major CD-ROM databases: ABI/INFORM Global, Newspaper Abstract, and Periodical Abstract using the key words "Information Systems" + "Outsourcing," for the decade from January 1985 to January 1995. A total of 197 companies were identified as known IS outsourcers.[2] Only 175 of the 197 were used in this study. The rest were discarded due to missing data. Table 1 summarizes some of the characteristics of the outsourcing contracts based on this data sample.

The different sample size of the three contract properties (Size, Length, and Cost) in the table are the result of incomplete information reported in the media for some IS outsourcing contracts.

4.2. Testing Methods

Two types of tests are conducted to determine which model best fits the observations of IS outsourcing adoption in the social systems of corporations. The first type estimates the model parameters of all four diffusion models using the nonlinear least squares regression method. The second type determines the true model among the four alternatives using the J- and P-test method developed by Davidson and MacKinnon (1981).

NLIN, a nonlinear regression procedure of the SAS software package, is used for estimating the parameters in the four diffusion models with both the LV92 and our expanded data sets. Since nonlinear regression is notorious for non-convergence or convergence at local minima, the starting values of these parameters are adjusted systematically to make the regression converge. When a nonlinear regression converges, it is

[2]The data set is available from the lead author upon request.

Table 1 **Characteristics of the Outsourcing Contracts**

	Sample Size	Max	Min	Mean (μ)	STD(σ)	Median
Contract Size (Million)	90	3600.00	0.60	392.20	763.11	78.95
Contract Length (Year)	115	12.00	1.00	6.58	3.07	5.00
Contract Cost (Million/Year)	71	320.00	0.20	38.65	62.16	16.00

conventionally run the second time with slightly different starting values to make sure it converges to a relatively stable point.

After the model parameters are estimated, the J-tests or P-tests, as described previously in §2.2, are conducted using each model in turn as the null hypothesis and the rest as the alternative hypotheses. Special care is exercised in grouping the null and alternative models to make sure that no nested models are tested against each other.

5. Results and Discussions

Based on the procedures described above, repeated nonlinearly regression were conducted using the full data set we collected to obtain stable estimates for the parameters in each of the five diffusion models. Table 2(a) presents the results of nonlinear least squares regressions.

5.1. Test the Null Hypothesis: White Noise Model

Given the estimated values of the parameters, we first use the white noise model defined in Equation (11) as the null hypothesis, and test its truth in the presence of the alternatives of internal (3), external (5), mixed (7), and Von Bertalanffy (9) models. Since the null model is linear, the J-test defined as the linear regression (14) is used. Table 2(b) presents the result.

The J-test result unequivocally rejects the null hypothesis that the adoption of IS outsourcing by the reported corporations is random. All four alternative models can reject the white noise model at the significance level of $p < 0.001$ or better. Thus we conclude that the diffusion of IS outsourcing is not a random process. This leaves us the task of determining which one of the four alternatives, if any, is the best model that explains the IS outsourcing diffusion process.

5.2. Test of Hypothesis I: Dominance of Mixed Influence Models

The three nonnested diffusion models, internal, external, and Von Bertalanffy mixed influence models, are tested against each other as both the null and alternatives using the P-test procedure, as defined by the linear regression (15). Table 2(c) presents the results.

Hypothesis I is strongly supported by the P-test results of Table 2(c). The null hypothesis, that the internal influence model is the true model, must be rejected when compared to the external, mixed, and von Bertalanffy models at the $p < 0.001$ significance level. The null hypothesis, that the external influence model is the true model, must also be rejected when compared to the internal, mixed, and von Bertalanffy models at the $p < 0.001$ significance level. However, the null hypothesis that the von Bertalanffy model is the true model cannot be rejected when compared to any

Table 2(a) Model Parameters Estimated by Nonlinear Least Squares Method

Parameter	Internal	External	Mixed	Bertalanffy
m	180.484	4747.099	189.599	232.773
m_0	9.348		8.952	2.348
p		0.00046	0.0014981	
q	0.000375		0.0003014	
b				0.0278466
θ				0.7529121
R^2-adjusted	0.998	0.995	0.998	0.999

Table 2(b) J-test Model Comparisons: *t* Values with Probabilities

	Alternative Models			
Null Model	Internal	External	Mixed	Bertalanffy
White Noise	11.95**** (0.000)	23.11**** (0.000)	11.84**** (0.000)	6.25**** (0.000)

****$p < 0.001$ ***$p < 0.005$ **$p < 0.01$ *$p < 0.05$

Table 2(c) P-test Model Comparisons: *t* Values with Probabilities

	Alternative Models		
Null Model	Internal	External	Bertalanffy
Internal	N/A	9.427**** (0.000)	10.901**** (0.000)
External	10.572**** (0.000)	N/A	16.669**** (0.000)
Bertalanffy	−0.025 (0.980)	0.119 (0.906)	N/A

****$p < 0.001$ ***$p < 0.005$ **$p < 0.01$ *$p < 0.05$

of the two fundamental diffusion models. Since the parameter θ has an estimated value of 0.7529, the von Bertalanffy model represents a flexible mixed influence diffusion model. Therefore, we conclude that the mixed influence model is dominant in the diffusion of IS outsourcing.

To determine whether the conclusions derived by LV92 still hold when the correct model parameters are estimated, we conduct nonlinear least squares regression tests using the four models and the LV92 data set. Tables 3(a) and 3(c) contain the results of these tests. Table 3(b) is adopted from Table 2(a) of LV92 (p. 347) for comparison.

Two major characteristics of the parameter estimates in Table 3(a) should be noted. First, they are close but not identical to the parameter values in Table 2(a) estimated with the full data set.[3] This is the result of the combination of flexibility of the diffusion models and the use of least square regression procedure for parameter estimation. Each diffusion model essentially represents an S-shaped curve with at least three parameters adjustable to fit the observation. When two data sets are used, even though the smaller one is a subset of the larger one, a well-converged nonlinear least square regression would likely generate two sets of different values for the same set of parameters to minimize the residual errors of each data set, as indicated by the high R^2-adjusted values in both tables for all the models. Ideally, the smaller data set would constitute a segment of the complete S-shaped diffusion curve. But in reality, due to sampling and random errors, the small segment may form a mini-S curve with nonidentical characteristics with the complete diffusion curve. Thus, in analyzing diffusion characteristics of an innovation, one should avoid using short-term data and small sample size. If necessary, the limitations should be clearly stated.

Second, it can be seen that these estimated parameter values are very different from the ones estimated by LV92 presented in Table 3(b). The most striking differences are the values of p and q, the coefficients of the diffusion rate in the external and internal, as well as the mixed models. The LV92 parameter values are approximately 100 times greater then our estimates.

[3]We thank the anonymous referee for pointing this out.

Table 3(a) Model Parameters Estimated with the LV92 Data Set

Parameter	Internal	External	Mixed	Bertalanffy
m	173.1057	2141.641	230.4397	331.2319
m_0	4.3843		1.0671	0.7867
p		0.000727	0.0016628	
q	0.0005843		0.0004093	
b				0.019097
θ				0.589169
R^2-adjusted	0.994	0.973	0.989	0.991

Table 3(b) Model Parameters Estimated By LV92

Parameter	Internal	External	Mixed
m	206.48	200.01	148.99
m_0			
p		0.0111	0.0097
q	0.0501		0.0427
R^2-adjusted	0.6315	0.4590	0.5472

Table 3(c) P-test Model Comparison: *t* Values with Probabilities

	Alternative Models		
Null Model	Internal	External	Bertalanffy
Internal	N/A	6.343*** (0.001)	4.460*** (0.001)
External	6.472*** (0.001)	N/A	5.011*** (0.001)
Bertalanffy	2.898** (0.008)	5.115*** (0.001)	N/A

****$p < 0.001$ ***$p < 0.005$ **$p < 0.01$ *$p < 0.05$

Yet, when the LV92 values are plugged into the original diffusion equations, they produce very poor estimates for the cumulative number of adopters at a given time point ($N(t)$). The internal model even produces a near constant $N(t)$ for any t values, regardless the values of m_0 which, unfortunately are omitted from the original table. This is perhaps the result of the nonlinear regressions settled into a local minima, given the complex structures of LV92 estimation equations. Or, perhaps the values were misprinted. However, since there are two other tables in LV92 that exhibit similar characteristics, misprinting does not seem likely.

With the new estimated values of the model parameters, we conduct the P-test using the internal, external, and Von Bertalanffy models in turn as the null model. Each model is tested against the others as alternatives, to see which, if any, one of these models is the true model. The results are shown in Table 3(c).

These results suggest that there is no dominant model when comparing the internal, external, and Von Bertalanffy mixed influence models. Each null model is rejected when the others are used as alternative models. This situation is not uncommon when the P-test is used. This inconclusive result is a clear indication that the data set used is inadequate, either because it is too small, or because large variations exist in the observations. Thus, we conclude that the hypothesis of the dominance of the internal influence model of IS outsourcing diffusion is not supported by this data set.

5.3. Test of Hypothesis II: Dominance of Von Bertalanffy Model

The previous tests established the dominance of the Von Bertalanffy mixed influence model in the absence of the fundamental mixed influence model which is nested with the internal and external models. It is only logical to test the two mixed models against each other to determine if flexible inflection diffusion models, like the Von Bertalanffy model, are indeed better than fixed inflection models. Since both models are non-linear, the P-test is used. For comparative purposes, tests using the full data set and the smaller LV92 data set are conducted. Tables 4(a) and (b) present the results.

Interestingly, the results suggest that the two mixed models fit equally well with the observations. Table 4(a) demonstrates that when the full data set is used, neither mixed model can reject the other as the true model at statistically significant levels. Table 4(b) illustrates that when the LV92 data set is used, each model can reject the other as the true model at statistically significant levels. Therefore, we conclude that Hypothesis II is not supported by the data of this study.

5.3. Test of Hypothesis III: The Kodak Effect

Is there a Kodak effect in the diffusion of IS outsourcing? We conduct pre- and post-Kodak tests using our data set. The results are presented in the Tables 5(a) and (b) for pre-Kodak era and in Table 6(a) and (b) for post-Kodak era.

The pre-Kodak test results suggest that both external and Von Bertalanffy models can reject the internal model at the significance level of $p < 0.05$ or better, and the external model can be rejected by the Von Bertalanffy model at the significance level of $p < 0.05$ or better. Among all three models, the Von Bertalanffy

Table 4(a) **P-test with the Full Data Set: *t* Values with Probability**

Null Model	Alternative Models: Mixed	Alternative Models: Bertalanffy
Mixed	N/A	1.256 (0.213)
Bertalanffy	0.183 (0.855)	N/A

$^{****}p < 0.001$ $^{***}p < 0.005$ $^{**}p < 0.01$ $^{*}p < 0.05$

Table 4(b) **P-test with the LV92 Data Set: *t* Values with Probability**

Null Model	Alternative Models: Mixed	Alternative Models: Bertalanffy
Mixed	N/A	−2.534* (0.018)
Bertalanffy	6.039**** (0.001)	N/A

$^{****}p < 0.001$ $^{***}p < 0.005$ $^{**}p < 0.01$ $^{*}p < 0.05$

Table 5(a) **Model Parameters Estimated with Pre-Kodak Data**

Parameter	Internal	External	Bertalanffy
m	20.747	259.270	37.331
m_0	1.154		0.00000025
p		0.005677	
q	0.018835		
b			0.075327
θ			0.321597
R^2-adjusted	0.992	0.992	0.995

Table 5(b) P-test Model Comparison: *t* Values with Probability

	Alternative Models		
Null Model	Internal	External	Bertalanffy
Internal	N/A	2.806* (0.017)	3.219** (0.008)
External	1.595 (0.137)	N/A	3.321** (0.006)
Bertalanffy	−0.100 (0.9190)	−0.430 (0.6777)	N/A

****$p < 0.001$ ***$p < 0.005$ **$p < 0.01$ *$p < 0.05$

Table 6(a) Model Parameters Estimated with Post-Kodak Data

Parameter	Internal	External	Bertalanffy
m	186.843	264.505	264.079
m_0	26.490		17.813
p		0.015799	
q	0.000331		
b			0.0195034
θ			0.4113924
R^2-adjusted	0.999	0.973	0.999

Table 6(b) P-test Model Comparison: *t* Values with Probability

	Alternative Models		
Null Model	Internal	External	Bertalanffy
Internal	N/A	7.785*** (0.001)	7.002*** (0.001)
External	10.976*** (0.001)	N/A	12.257*** (0.001)
Bertalanffy	0.783 (0.437)	0.647 (0.520)	N/A

****$p < 0.001$ ***$p < 0.005$ **$p < 0.01$ *$p < 0.05$

mixed influence model can not be rejected by any alternatives. Thus, we conclude that the Von Bertalanffy model is the best model for the diffusion of IS outsourcing in the pre-Kodak era. However, caution should be exercised because the data set is small (only 15 observations), which leads to the extremely small estimate of the m_0.

With a much larger data set (67 observations), the P-test clearly shows that the Von Bertalanffy mixed influence model is the best model among the three alternatives: it can reject the other two models, and no other model can reject it. This confirms the conclusions based on Table 2(c) that the mixed influence model dominates IS outsourcing diffusion

Comparing this to the results of Table 5(b), it can be concluded that there is no significant difference between the influence sources of the diffusion of IS outsourcing, before and after the Kodak announcement. Thus, we conclude that Hypothesis III is not supported by the data set.

6. Conclusion

Our analysis of the influence sources of IS outsourcing using the data set of 175 companies, as well as the LV92 data set of 60 companies, clearly indicates that the mixed influence model best describes the diffusion process of IS outsourcing. This leads us to conclude that it is the combined effects of external media, vendor pressure, and internal communications at the personal level among managers of companies that significantly influenced the decision to adopt IS outsourcing. Furthermore, we found no evidence suggesting that the Kodak outsourcing agreement with IBM and two other vendors in July of 1989 significantly changed the characteristics of the IS outsourcing diffusion from the influence sources point of view.

Thus, our results directly contradict the findings of LV92. Differences in the sample sizes of the two studies may have played a role in creating these contradictions. However, model and estimation errors obviously damped the validity of LV92's conclusions. Given the widespread influence of the LV92 study, this debate is both significant and beneficial.

Diffusion models have many underlying assumptions which may or may not be satisfied under the conditions of IS outsourcing. Awareness of these limitations will certainly assist in the interpreting the statistical results, as well as in generalizing the conclusions. We suggest further refinement and testing of mixed influence models. For instance, mixed influence models may be refined to satisfy assumptions that are presently violated by the internal, external and mixed influence models. Specifically, these models permit only one adoption by an adopting unit, and no rescinding of the adoption. That is, once a company outsources, it does not insource again. Furthermore, the models are based on a distinct and constant ceiling. That is, the potential number of adopters in a social system does not increase or decrease during the diffusion process.

Another effect of the underlying assumptions of the diffusion models is clearly demonstrated in the estimated value of m in different models. As shown in Tables 2(a), 3(a), and 5(a), the value of m is large in the fundamental mixed influence model, compared to the m's in the other models, even though the goodness of fit as measured by R^2-adj is almost the same across models. This may be attributed to the structure of the diffusion models used in this study. In the internal and mixed influence models, it is assumed that there is a complete mixing of social system members (Mahajan and Peterson, 1985). That is, it is assumed there is a complete, pairwise interaction between prior adopters and potential adopters. In these models, a smaller social system would suffice to sustain the diffusion rate observed. In the case of the external model, it is assumed that each social system member is independent, and influenced only by external factors. Only a subset of members experiencing the influences will adopt. To reach the same rate of diffusion, a larger number of potential adopters is certainly required than in the cases of internal and mixed influences.

In furthering science, it is important to question and validate previous research. We acknowledge the contribution of LV92 in using diffusion of innovation models and the Davidson and Mackinnon tests in IS studies. This combination is a powerful tool in the study of innovation diffusion because there are so many diffusion models. We offer criticism that we hope will constructively spur the development and refinement of models to better understand the diffusion of the ever-increasing outsourcing phenomenon. Our improved estimates using an expanded data set and our findings about the superiority of the mixed influence models suggest the importance of further refining innovation diffusion models and the testing procedures to understand the interesting phenomena of IS outsourcing, as well as other IS/IT innovation diffusions.[4]

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