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Expert systems diffusion in British banking: Diffusion models and media factor

Yuan Pu Shao*

BizIT Consulting, 60 Palmerston Avenue, Toronto, ON. M6J 2J1, Canada

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Abstract

A study of 20 British banking organizations was carried out to test the applicability of some innovation diffusion models on the adoption of expert systems (ES) in industry. Secondary data, postal questionnaires, and in-depth telephone and field interviews with IT directors or leaders of knowledge-based teams were used. The study determined, within this setting, that: ES diffusion is best described by a mixed-influence model, ES adoptions are positively associated with media coverage in a lagged-mode, and that larger organizations adopt ES earlier than smaller firms, but that the Pareto distribution was rejected.

Keywords: Banking; Diffusion models; Expert systems; Innovation diffusion; UK

1. Introduction

In order to survive and prosper, organizations have become faster, leaner, more customer-oriented and more conscious of cost than they have ever been before. Technology deployment has been one of the ways to increase business competitiveness. Expert systems (ES) have been widely used in many industries, such as medical, engineering and manufacturing (e.g. see Refs. [2, 4, 16, 20, 22]) to achieve this. Since the 1980s, examples of ES that were used by banking institutions have been discussed in IS, management and banking literature (e.g. see Refs. [3, 5, 6, 13, 15, 27, 30]).

However, research has focused on application development and there has been little or no attempt to relate ES to other issues that affect the whole process of ES deployment [14]; this is probably because ES were new to industries. As a result, though there has been much research on ES development and success (e.g. see Refs. [7, 8, 10]), there has been little on ES diffusion.

The objective of this study is to investigate the diffusion of expert systems in the British banking sector.

2. Literature review

Innovation diffusion literature has generally focused on the process by which adoption occurs; i.e. the demand aspect of diffusion. This perspective is summarised in Ref. [25]. According to this theory, the adoption of an innovation is primarily the outcome of a learning or communications process. As a result, a

*Corresponding author. E-mail: shao@globalserve.net

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fundamental step in examining the process is to identify factors related to the effective flow of information and of the characteristics of its flows, its reception, and resistance to its adoption; these involve an individual's general propensity to adopt innovation, or the person's innovativeness, and the congruence between innovation and its social, economic, and psychological characteristics [1]. In fact, the classical theory of diffusion emphasises the role of communication in the innovation diffusion process: the adoption process includes a series of stages that are influenced in different ways by various information channels.

Models, as a means of understanding diffusion patterns, have existed in one form or another for many years. However, only recently have they been rigorously examined and their properties investigated. Even so, much remains to be done from both a practical and theoretical perspective.

Some prior research examined the relationship between external information channels and the diffusion of software process innovations in organizations [11]. However, only Nilakanta and Scamell [21] modelled the diffusion process as a series of stages, specifically focusing on the influence of different information channels on the diffusion of radical and incremental database design technologies. Zmud [31] limited his analysis to a higher level and investigated the association between different information channels and the overall use of technical and administrative software practices and found a positive relationship between mass media availability (e.g. journal subscriptions) and the use of modern technical practices. Different sources were found to influence the diffusion of radical and incremental innovations, and 'more sources' were found to influence the diffusion of radical innovation. Based on this, it is apparent that limited understanding exists of the relationships between information channels (and media coverage) and the diffusion of technological innovation.

Another major factor is the process of adoption by the firm. Technological innovations are new production inputs, machines, processes, and techniques that are adopted by firms or entrepreneurs [19]. In general, the firm adoption decision has been seen as a function of: the characteristics of the innovation, such as its profitability, or cost savings versus its required investment; industry characteristics, such as the intra-industry competitive structure and the nature of previous technological investment; institutional effects, such as societal concerns and political actions, and firm characteristics, such as the size, aggressiveness, and innovativeness of management and the degree of information about the innovation.

There are many studies of innovation diffusion (e.g. see Refs. [12, 23, 24, 29]) in areas such as electronic data interchange (EDI), computing, CASE tools, etc. They have been studied in terms of their relative advantage, compatibility, complexity, trialability, observability.

The diffusion of ES can be defined as the process by which an expert system is "communicated through certain channels over time among the members of a social system" [26]. There are four key elements in this process: the ES itself, channels of communications, time, and the social system. The issue of ES adoption is a complex one, as adopting a particular technology in an organization depends on many factors, such as general economic environments, organizational factors, and features of the technology.

3. The research project

All thirteen UK high street banks and the top thirteen building societies (those with over GBP 3000 million assets and over 1000 employees) were selected for inclusion in the study. Postal questionnaires, telephone interviews, and field visits were used to collect data. Twenty of the 26 agreed to participate in the study, though not all to the same degree. The institutions that took part had average assets of about GBP 29 000 million, an average of about 22 400 employees and an average of about 820 branches. These values are higher than the population averages.

Telephone interviews were conducted in November and December 1993, while site visits were conducted in March 1994. Telephone interviews varied in length from 25 to 45 min. Seventeen IT directors or heads of knowledge system groups were interviewed by phone. Five face-to-face interviews were conducted after the telephone interviews. On average, 40 min were spent on each interview, though one lasted for 90 min. Annual financial reports of various banking organizations were used to collect financial information, which was also obtained from the *Banker's Almanac* and *Yearbook of Building Societies*, e.g. for statistics on

the number of retail branches and the number of employees, etc. Media coverage for expert systems was also sought through major British banking journals and the *Financial Times*.

4. ES diffusion: Fundamental diffusion models

The aggregated historical data on ES adoptions in the British banking sector are presented in Table 1. In this, the row of ES adopters shows the number of fresh ES adopting banking organizations in each year. The total number of potential adopters is 20; i.e. this is the number of responding organizations.

The cumulative adoptions are plotted and presented in Fig. 1.

The initial slope is gradual, indicating relatively slow diffusion, but later it increases before turning into a flat line, indicating the apparent stagnation of ES diffusion into the banking organizations under investigation. Furthermore, the two ES planners who replied that they would develop expert systems in 1993 and 1994 were not included, as adoption studies use only actual adopters. Nevertheless, the curve corresponds to the *S*-shaped distribution that is extensively documented.

Studies using or attempting to validate widely accepted models are not, of course, able to determine empirically which of several competing distribution functions best describes a given diffusion curve. Therefore, efforts were made to compare three fundamental diffusion models: the external, internal, and mixed-influence models (for details of these, see [17]).

A non-linear regression analysis algorithm was used to define the parameters of the three different models. These were estimated from time-series data (1985–1994). For assessing the goodness of fit of the models, emphasis was placed on the explanatory ability of the models used. For this purpose, the coefficient of determination (R^2), the residual mean square (s^2) were estimated. R^2 is a measure of the goodness of fit of a particular model. The F statistic also serves to test how well the regression fits the data. The best model was considered to be the one that showed relatively high R^2 and relatively small standard errors of estimated parameters. s^2 is another measure for comparing fitness of models to actual values. Another useful summary statistic, S, is the standard error of the estimate. Table 2 summarises the results of the comparisons.

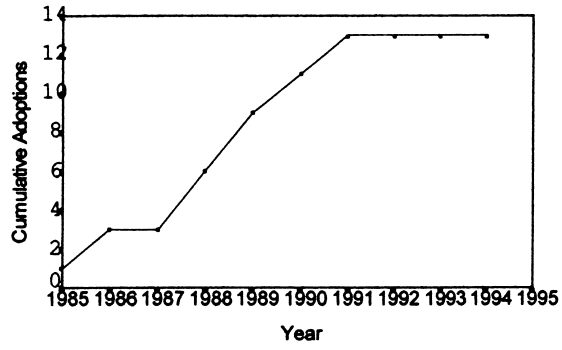

Fig. 1. ES diffusion scatter plot.

Table 3 shows the actual and predicted values when using the three fundamental diffusion models. The statistical testings obtained by non-linear regressions give some interesting results. Here, the external and mixed-influence models have comparable results and

Table 2
Parameter estimates, fit statistics for ES diffusion in British banking

Parameters	External influence	Internal influence	Mixed influence
a	0.11 (0.01) [a]		0.11 (0.03)
b		0.53 (0.04)	0.00 (0.00)
R^2	0.91	0.77	0.94
F	437	163	316
s^2	2.09	5.44	1.46

[a] The figures in parentheses are standard errors of the parameter estimates.

Table 1
Number of adoptions of expert systems in the British banking industry per year

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
ES adopters	1	2	0	3	3	3	2	0	0	0
Cumulative adoptions	1	3	3	6	9	11	13	13	13	13

Table 3
Comparison of actual adoptions and predicted values of three models

Year	Actual	External	Internal	Mixed
1	1	2	1	1
2	3	4	2	3
3	3	6	3	5
4	6	7	4	7
5	9	9	6	8
6	11	10	9	10
7	13	11	11	11
8	13	12	14	12
9	13	13	16	13
10	13	14	17	14
S		1.45	2.3	1.21

are more appropriate than the internal-influence model. However, taken collectively, the mixed-influence model explained diffusion pattern best.

5. ES diffusion: Media factor and ES adoption

We next attempted to determine whether there was a correlation between ES adoptions and media coverage, both at the same time and in a lagged mode. For each respondent banking organization, information on the year of adoption of expert systems and the number of existing expert systems or knowledge systems adopters were collected. Table 4 is the contingency table depicting these sets of data together with data on ES media coverage. For information channels, the study collected data from the *Financial Times*, *The Banker* and the *Banking World*. These are the most widely read media in British banking. The number of articles on artificial intelligence, expert systems, knowledge-based systems, or neural networks were collected, along with the year. Relevant articles in the *Banker*, the *Banking World* were particularly annotated for clarity of the subject matter.

The graphs of combined media coverage and number of adopters are plotted against each year in Fig. 2. Correlation analysis on the relationship between combined media coverage and the adoption of expert systems was then performed. The Pearson product coefficient was -0.09, the statistical significance (p) was 0.08. This indicates that the null hypothesis has to be retained and there is no significant correlation between these media coverage and ES adoptions.

However, a further look at the graphs yield an interesting result. Let *ADP* be the frequency of the ES adopted and *MED* be the combined frequency of articles published. Two types of linear regression analyses can then be performed.

The first assumed that there is no time lag between media channels and frequency of ES usage in the British banking sector. The result indicated no plausible regression between the number of articles published in the combined media; there was no plausible relationships between these two sets of variables.

The second analysis was directed towards regression analysis in time-lagged mode. Several regres-

Table 4
Data on media channels and number of ES adoptions

Media	Year									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
FT [a]	n/a	30	22	16	15	13	7	6	33	31
FT [a] (/12)	n/a	2.5	1.8	1.33	1.25	1.1	0.58	0.5	2.75	2.58
BKR [b]	0	3	0	1	0	0	0	1	0	1
BW [c]	0	1	1	1	0	0	0	0	0	0
Combine [d]	n/a	2.2	0.93	1.11	0.42	0.37	0.2	0.5	0.92	0.85
ES adopters [e]	1	2	0	3	3	3	2	0	0	0

[a] Financial Times.
[b] The Banker.
[c] Banking World.
[d] Combination of the three media frequencies (averaged).
[d] Frequency of ES adoptions at that year.

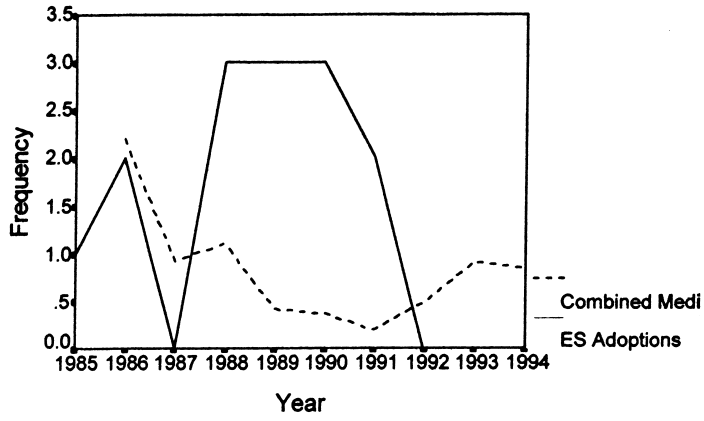

Fig. 2. Scatter plots for both combined media coverage and ES adoptions.

sions were performed with different time lags to identify some possible relationships between these two variables. One assumed a two year lag after the media coverage (the two years' time lag was obtained by observing the peaks of both combined media frequencies and ES usage). Statistical result indicated that this does not occur. Several different time lags were then assumed and there are two possible positive results:

$$\underset{(1.19)(2.76)}{\text{MED} = 0.18 + 0.18\text{ADP}(-4)} \quad (1)$$

R^2 adjusted=0.57, DW=2.39, $F(1, 4)$=7.61.
This equation suggests that media coverage is positively impacted by the number of ES adopters four years earlier. Statistically, the result is quite good, with test parameters well in the acceptable range.

$$\underset{(-0.24)(3.02)}{\text{ADP} = -0.146 + 1.7\text{MED}(-3)} \quad (2)$$

R^2 adjusted=0.62, DW=2.059, F (1, 4)=9.01
This result of this equation suggests that the time lag is three years when media coverage has a positive impact on the adoption. Statistically, the result is quite good, with test parameters well in the acceptable range.

Although there are certain relationships among media and technology adoption, the diffusion of information technology into organizations also depends on many other factors that make the penetration possible.

6. ES diffusion: The firm adoption model

In modelling diffusion of technological innovation, an important relationship is the one between firm size and time of adoption. A common assumption is that, because large firms are more able to afford the risk and cost associated with innovations, the time order of adoption will vary inversely with firm size; i.e. larger firms adopt earlier and smaller firms later. Table 5 shows the empirical data used to test this assumption. The null hypothesis is: The timing of ES adoption do not vary inversely with firm size.

The scatter plot of the data is presented in Fig. 3. The product moment correlation coefficient $r=-0.52$.

Table 5
Size of organizations and timing of ES adoptions

Bank	Asset % over the total	Year of adoption ES
1	2.8%	1990
2	0.5%	1990
3	26%	1985
4	9.7%	1986
5	23%	1989
6	0.5%	1991
7	4.7%	1986
8	4.7%	1988
9	11.2%	1989
10	3.5%	1990
11	3.5%	1989
12	3.3%	1991
13	2.2%	1988
14	4.4%	1988

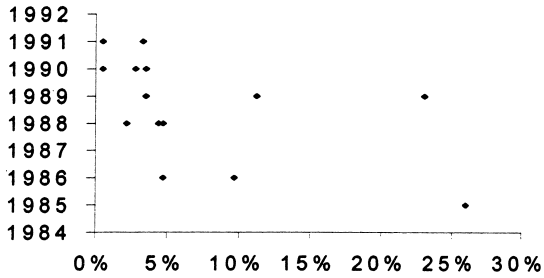

Fig. 3. Scatter plot of timing and adoption year.

Degree of freedom are given by $n-2=12$. $t=-2.12$. The computed significance level is 5.5%.

Thus, the null hypothesis is rejected and there is a modest negative correlation between the size of banking corporations and the timing of ES adoption.

A non-linear regression was performed to test the innovation adoption model further. The Pareto model was described as ($y=d^*x^{-k}$). Year is the date by which firms of x or larger will adopt or the date of adoption by a firm of size x, and d is the date of adoption by the smallest firm or the latest adoption date. Similarly, k indicates the range of adoption times among the set of firms. Thus, if the value of k is small, the adoption times for firms of all sizes are similar, and diffusion through the set of firms is rapid. Alternatively, in a slow diffusion process, k is larger, indicating a greater range in adoption times.

The non-linear regression results are given in Table 6 below. For evaluating the fitness of the power function to the actual data observed, the coefficient of determination (R^2), the residual mean square (s^2) were estimated. R^2 is a measure of the goodness of fit of a particular model. The better model was considered to be the one which showed relative high R^2 and relatively small standard errors of estimated parameters.

Table 6
Tests for Pareto model of firm adoption for ES in UK banking

$y=d^*x^{-k}$	d	k
Estimates	5.93	0.20
Standard errors	0.66	0.08
$R^2=0.36$		
$F=63.83$		
$t=7.99$		
$S^2=2.42$		

With these statistical analyses, although there is a modest negative correlation between the timing of ES adoption and the size of banking organizations, the documented Pareto distribution ($y=d^*x^{-k}$) is not supported by this study.

7. Conclusions

The diffusion of expert systems in British banking best fits the mixed-influence model of innovation. It also fits the external-influence model quite well. This indicates that ES diffusion is frequently associated with external influence. One of the dominant factors in the external-influence model is the effect of mass media communication on the diffusion process, to a lesser extent of government agencies and salespeople. The rejection of the internal-influence model shows the limited extent of interpersonal contacts in ES diffusion for the banking setting. Apparently, ES adoptions in organizations are kept secret for a time to retain their competitive edge, unlike the traditional innovation diffusion theory where consumer products rely heavily on internal communications (personal contacting). Thus, the channels of communications do affect ES diffusion.

ES adoptions are positively related to media coverage with a time lag. Communication channels affect the diffusion of innovation, with a strong correlation between mass media coverage and ES diffusion in banking. Regression analyses reveal that the media coverage positively affects ES adopters after about four years; similarly, the number of ES adopters is positively associated with media coverage about three years earlier.

Larger firms adopt earlier than smaller firms. The firm adoption model of innovation (e.g. see Refs. [9, 18]) was supported by this study. However, the Pareto distribution was not supported. This would suggest that firm size alone would not explain ES diffusion satisfactorily, as other factors, such as cost and perceived benefits, may contribute towards the diffusion process.

The diffusion of expert systems in the British banking organizations follows an *S*-shaped curve and can best be described by mixed-influence model.

Several assumptions that underlie the fundamental diffusion model must be recognised before it is applied or results are further interpreted.

First, various diffusion models are simplifying assumptions designed to facilitate analytical solutions to the model. One such assumption is that the diffusion process is binary [28]. Members of a social system either adopt the innovation or they do not. Thus, adoption is treated as a discrete rather than continuous event. As a consequence of this assumption, the fundamental diffusion model does not take into account stages in the adoption process (e.g. awareness, knowledge, etc.). In this study, there were two organizations that were planning to adopt ES but were excluded.

Second, fundamental diffusion models are based on the assumption that there is a distinct and constant ceiling (N) on the number of potential adopters in the social system and that this ceiling is either known or can be estimated. As a result, the fundamental diffusion model is static; the social system (the banking organizations in this case) is not allowed to increase or decrease in size during the course of the diffusion process. In this study, mergers or new entrants to the sector could change ES diffusion.

Third, the fundamental diffusion models only permit one adoption by an organization. Multiple adoptions of the same innovation by a single adopting organization are not considered. A simultaneous assumption is that an adoption cannot be rescinded. However, several ES adoptions occurred in some banking organizations and this was not considered in modelling the ES diffusion.

In addition, it is assumed that the innovation itself does not change over the whole process of diffusion. This means, for example, that modifications do not take place. Moreover, the innovation is assumed to be independent of other innovations. Thus, adoption of the innovation does not complement, substitute for, detract from, or enhance the adoption of any other innovation. In this study, expert systems have been evolving and new innovations in the area, such as neural networks, could also be considered.

However, this study has some special limitations. Firstly, the number of actual respondent organizations represented 77% of the retail banks and leading building societies, which suggests that the sample was typical for large retail banking organizations, but it was not the total population of the banking organizations in the UK. Secondly, other research in innovation diffusion has used relatively fewer data points to study diffusion models, and this has proven useful and valid. Thirdly, the relationship between the ES adoption and the media factor needs to be studied further. Although the interviews with respondents revealed that the three publications were widely read by banking staff, the limited coverage in terms of the overall media in the UK may impose a bias towards the relationship between ES diffusion and media coverage.

The findings have a few practical implications. Three implications are seen. First, the model can be used by practitioners to describe and model behavioural events such as diffusion of ES in other areas. Second, the importance of the association between media coverage and ES adoption would contribute considerably towards the dissemination of innovations and innovation studies. The models can be used as a marketing tool for developers of expert systems: technology marketers should pay attention to external influences, such as communication channels and sales agents. Third, the model can be used for forecasting the adoption of the technology.

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Mr. Yuan Pu Shao is a principal consultant at BizIT Consulting, Toronto, Canada. His research and consulting focus on IT-enabled business process re-engineering, the application of advanced information technologies in financial organizations, IT management in organizational transformation and development, and virtual organizations. He also lectures at the Ryerson Polytechnic University on Information Systems Planning and Development. His research publications have appeared in *Expert Systems with Applications*, *International Journal of Information Management*, *Journal of Object-Oriented Programming*, *International Journal of Intelligent Systems in Management*, *Finance and Accounting*, *Journal of Information Sciences* and the proceedings of various international conferences. Mr. Shao has a B.Sc. in Physics and M.Sc. in Information Systems. He can be reached by e-mail at shao@globalserve.net.