Strategic Management Journal, Vol. 13, 29–46 (1992)

THE DIFFUSION OF TECHNOLOGICAL INNOVATION IN THE COMMERCIAL BANKING INDUSTRY

JOHANNES M. PENNINGS
The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania, U.S.A.

FARID HARIANTO
Institute of Management Education, Jakarta, Indonesia

This paper examines the propensity of organizations to adopt technological innovations. Technological innovations evolve from the stock of skills which organizations have accumulated over time. Linkages with extramural sources of technology are presumed to be important as well. Hypotheses are tested on a sample of commercial banks. Findings show that prior experience in information technology, in tandem with a variety of interfirm linkages, will affect the banks' decision to adopt this innovation.

INTRODUCTION

This paper examines the propensity of organizations to adopt technological innovations. We start from the assumption that such innovations are a direct outgrowth of skills and abilities which have been accumulated in the past. Following Nelson and Winter (1982), we can construe firms as a repository of skills and abilities. This stock of skills gives a firm strategic leverage to pursue certain innovations but also limits discretion as to the direction or content of its innovative efforts. Technological innovations evolve from a firm's past accomplishments and in turn furnish a new assortment of skills.

Innovation represents the adoption of a new idea, process, product or service, developed internally or acquired from the external environment. The adoption of innovation follows from and is contingent upon an organization's repertoire of technical, strategic and administrative skills (Nelson and Winter, 1982). These skills combine with extramural sources of know-how. Prominent among these are other organizations—whether competitors or firms in other industries—whose know-how is germane to innovative efforts. Technological spillover from competitors and from extra-industry sources becomes accessible through the presence of interfirm linkages. During a firm's life, networks of interorganizational relationships are developed. Such relationships broaden environmental exposure and reduce the distance which a firm has to bridge when it reaches out to external know-how to adopt technological innovations.

These conditions—technological experiences and linkages with other firms—are crucial for explaining innovation and form the cornerstone of the present study. We seek to explain why some firms innovate, and, if they do so, why they innovate in a particular direction. In this regard we will consider a firm's past and its external environment. Elements of a dynamic theory of organizational innovation, involving past experiences and interfirm linkages, are formulated below. We subsequently set out to study a sample of organizations over time to examine how their innovative behavior was affected by the past. These conditions include various technological skills which are germane to the innovation under study, along with interfirm

Key words: technological innovations, firm skills, interfirm linkages, learning, service

0143–2095/92/010029–18$09.00

Received 14 February 1990
final revision received 10 July 1991

linkages that funnel extramural know-how into the firm.

The empirical study is based on the adoption of video banking by U.S. commercial banks during the period 1977–87. Video banking is an innovation. It is also a particular kind of innovation, permitting us to answer the earlier question of direction or content of innovation. We believe that the banking industry provides an ideal setting for testing a history-based theory about organizational innovation. While its testing is sector specific, the results could, however, be generalized to cover other types of organizations and different classes of innovations. This study, we believe, will demonstrate the virtues of longitudinal research and provide important advances in innovation research that go beyond the financial services sector.

BACKGROUND

Elements of a theory

Two sets of innovation factors—external networking and accumulated know-how—are the core ingredients of our theoretical framework on organization innovation. This position represents a continuation of the theme promulgated in 'classic' books, such as Schumpeter's, *The Theory of Economic Development* (1934), which argues that innovation is merely a recombination of existing skills, resources and other assets. However, innovation need not be restricted to the single firm but also occurs frequently under interfirm umbrellas. For example, data transmission and storage have become heavily amalgamated, rendering the distinction between telecommunication (transmission) and computer (storage) technology fuzzy.

We believe that a firm will enjoy a major innovation advantage if it can manage the flow of ideas that enter across its boundaries. This advantage is major when the firm belongs to an industry that undergoes an infiltration of 'alien' technologies—for example biotechnology into the pharmaceutical, and semiconductors into machine tool industries. The merging of disparate skills, spanning different industries, is facilitated by the networking resulting from interorganizational relationships.

Consistent with Schumpeter (1934) and Nelson and Winter (1982), we define innovation as a qualitative recombination of know-how residing in their human and capital assets. Many of a firm's skills cannot be transferred because the current stock of skills focuses the efforts of people in organizations in specific directions. The improvement of existing deficiencies is inspired by or predicated on currently available know-how and is therefore consistent with the old notion that organizational search is 'problemistic' (Cyert and March, 1963). New solutions are similar to or in the neighborhood of current solutions. On the voyage to new territories we are attracted to what looks familiar to or consistent with what we already know.

These comments are in accord with the literature on first mover advantages. Early adopters of new technology acquire non-trivial advantages over laggards (Lieberman and Montgomery, 1988). When prior technology is an integral part of new technology, mimicking is difficult and first mover advantages of innovating firms occur.

We argue that where firms innovate, they should consider extramural knowledge, particularly when the firm is specialized and encounters an intrusion of new technologies. Aggressive networking can enhance the benefits of first movers and reduce the uncertainty which the encroaching technologies create.

Since firms usually face a distance between proprietary and extraneous technologies, innovation helps bridge this distance. The smaller this distance, the greater the likelihood that firms will adopt new technologies. Prior experience with new technologies shortens the distance, and so does networking with extramural sources. Networking attenuates the limits of home grown skills which could thwart innovation. When a firm has no, or only a few, relevant partners, and if its proprietary skills are remote from those required for an innovation, it is less likely to innovate. If a firm seeks to short-circuit the distance between the present and future state, we would expect a higher likelihood of innovation failure (Kazanjian and Drazin, 1987).

Service vs. manufacturing

Most studies of innovation have been based on manufacturing organizations. Thus, a major research preoccupation has been with process vs. product innovation (compare Abernathy and

Utterback, 1978). Much of our knowledge of organizational innovation is really manufacturing and product innovation.

This bias toward the manufacturing sector is remarkable in view of its declining role in Western societies. Less than one in five individuals is currently employed in manufacturing, and this proportion continues to shrink. On the other hand, the service sector is growing phenomenally. Its growth is partly dependent on the infusion of information technology, which has enabled many of these firms to deal with explosive information processing requirements. Many service sectors have given us laboratories for examining the emergence of organizational networks spanning multiple industries. Innovation rates in the service sector are astounding (*The Economist*, 1989).

It is beginning to appear that the infusion of information technology takes a different form and follows a different path from innovation in the manufacturing sector. However, until 1980, information technology was traditionally alien to such service sectors as transportation, travel, banking and insurance, health care, and telecommunications. In many of these sectors, there is a strong need for interfirm coordination to manage interdependencies which arise during the production and delivery of services. It should therefore not surprise us that we are witnessing a proliferation of interorganizational structures such as airline reservation systems, credit card consortia and health maintenance organizations. While interorganizational linkages also occur in the manufacturing sector they tend to have a short longevity and appear to be largely faddish (Kogut, 1988).

TRENDS IN BANKING

The financial services sector is an interesting case for innovation researchers. Commercial banks have been very prolific in the establishment of joint ventures, licensing arrangements, and other types of interfirm partnerships. They have been major players in the merger and acquisition wave of the eighties (Harianto and Pennings, 1990) and have also been important users of R&D generated in other sectors.

Despite its popular image as a staid, heavily regulated industry, commercial banks have undergone significant transformations since 1975 (*The Economist*, 1989). Information technology is profoundly altering internal operations and delivery of financial services. Although the financial services sector resembles other service sectors in being outside the mainstream of innovation research, one segment—banking—provides a fruitful setting in which to test hypotheses because of the technological transformations which have occurred.

Banking parallels other service providing sectors such as telecommunications and transportation. In all these industries, firms have become more proximate because service delivery necessitates interorganizational coordination. Proximity, whether due to service complementarity or geographic vicinity, is an important inducement for innovation (e.g. Enright, 1989, Abrahamson and Rosenkopf, 1990). Proximity enhances communication, diminishes thresholds for resource sharing and accelerates the diffusion process. Compared with manufacturing, these sectors exhibit diminished technological separability (Williamson, 1975).

Commercial banks have established check clearing houses, have engaged in correspondence banking, and have also created alliances to develop and share new technologies. These linkages have been supplemented by other connections with other service providers; most significantly computer and telecommunications firms. Financial transactions require banks to pool their operations, and thus high levels of networking within and across sectors have become standard.

This networking is most visibly illustrated by automated teller machines (ATM). ATM involves both telecommunications and computer technology, and could not have been adopted without the benefit of commensurate learning curves. For example, ATM requires data storage and processing and is tied to other components in a bank's information system. Even more pronounced are its interbank linkages; interfirm networking is particularly noticeable around ATM.

In addition to their proclivity to form webs of interfirm networks, commercial banks have become major users of information technology, especially computers and telecommunications. In terms of dollar output, financial services absorbed almost 66 percent of the total revenue of the information industry in the period 1970–80

(Compaine, 1984). Indeed, this sector is under going a microelectronic influx and is by far the most important user of U.S. information technology. Harianto and Pennings (1990), who rely on Scherer's (1982) estimates, observe that as far back as 1974, the financial service sector absorbed most of the R&D outlays of the computer industry, rendering them highly symbiotic. They also reveal that banks have an unabating appetite for new technology, which in fact has accelerated after the publication date of the Scherer study (1982).

The capacity of commercial banks to innovate around information technology depends very much on whether they themselves have participated in the development of cumulated computer skills, endowing them with what Cohen and Levinthal (1989) call 'absorptive capacity.' This capacity diminishes the threshold for extracting know-how from others. Through interfirm channels, banks will have easier access to different but complementary technology. Such channels point to the importance of external conditions that are conducive to innovation. Some types of networks and the skills employed in forming them indicate a proclivity towards other types of interfirm relationships—for example, with computer firms. And such exposure to extramural technology, together with spillovers from competing banks, enhances their current capacity to adopt new technology.

Combination of new technology and networking: Video banking

The empirical research in this study addresses the introduction of a specific new form of information technology: video banking services. This innovation represents another illustration of the spreading of new technology into the service sector.

In general, videotex refers to computer-based interactive systems that electronically deliver screen text, numbers and graphics. It also permits interactions: for example purchasing an airline ticket, transferring funds between bank accounts, or trading for one's own securities account. Videotex brings together firms from the information delivery, financial and merchandizing sectors on one side (as information and service providers) and computer and telecommunications firms on the other (as providers of systems and communication networks for the delivery of such information and services). Video banking requires a great deal of interfirm coordination. Any organization considering the adoption of video banking needs significant skills in information technology and stands to benefit from connections with firms that furnish pertinent hardware and software.

By focusing upon a single innovation, we can compare firms which embarked on the innovation with those that did not. Longitudinally, we relate video banking to interorganizational activities and specific technology skills. Innovation is still a poorly understood phenomenon, and its antecedents appear only accessible if the research design allows a high degree of control of the history leading up to the innovation event.

HYPOTHESES

We agree with Mohr (1982) that it is more productive to create middle-range theories that fit specific innovations, whose specific antecedents can be identified and measured. Therefore, it is more crucial to identify the innovation than to develop general theories which account for any kind of innovation. Such a perspective is analogous to epidemiology and biology in which the diffusion of distinct diseases or organisms can be traced to particular antecedents which occur in a specific sequence. For any innovation, we need to be aware of the cumulative experiences, the ingredients of which become refashioned into the new product or service. The implication is that we should measure those experiences which are germane to video banking.

For banks, the relevant technological skills required to introduce video banking/videotex services include back office automation and transaction oriented technology. We hypothesize, therefore, as follows:

> *Hypothesis 1: that the more firms have accumulated experiences in computer and telecommunication areas, the higher the likelihood that they will embark on the video banking services.*

Amassed experiences can also be represented by the concept of 'learning by doing' (Arrow, 1962), which results in improved efficiency

because the firm has increasingly fine-tuned its routines. Conventionally, this approach is distinguished from 'learning by using,' where learning refers to enhanced capacity to do other things than what a firm has already accomplished (compare Rosenberg, 1982). Increased investment in capital goods reflects learning by doing and permits a firm to produce its output more efficiently. High levels of capital investment should also signal a readiness to expand investment programs into new generations of equipment to further secure efficiency benefits. Such investment also promotes a firm's 'absorptive capacity' (Cohen and Levinthal, 1989).

Lieberman (1984) has likewise argued that capital investments can be construed as an absorption of new technology, with the caveat that the more specific the type of capital investments, the more valid is the inference about a firm's application of information technology. A firm's capital investment history and its accrued performance reflect accumulated experience, which in turn reflects a propensity to allocate capital expenditures to new technologies such as video banking. This argument is analogous to that of Amit, Livnat and Zarowin (1989), who claim that a firm's capital expenditures pattern will induce it to finance internal diversification through similar capital expenditures programs. The conduct of these firms is quite different from firms that resort to acquisitive diversification. We contend that firms with comparatively high levels of capital expenditures will display a higher propensity to invest in videotex. Therefore:

> *Hypothesis 2: the higher capital investments in systems and equipment, or their derived productivity index, the more likely that firm will engage in video banking services.*

We mentioned earlier that firms operating in a web of interindustry linkages enjoy access to extramural technologies. We distinguish two types of linkages. The first class contains various information technology firms. Their technologies represent a powerful motive for joint ventures and affect the choice of strategic partners. Other linkages are confined to the banking sector, and similarly enhance spillover of ideas.

We have indicated that there is a mutual dependence between the financial sector and the computer and telecommunications industries. This interdependence is manifest in the volume of technology transactions and the proliferation of interfirm networking. Other sectors with noticeable (albeit less documented) networking *vis-à-vis* the financial sector are retailing and publishing. The proliferation of point-of-sales networks requires some sort of arrangement with retailers at the local, regional or national level. Similarly, providing basic financial services (e.g. stock brokerage) may involve the use of data bases offered by publishing houses. These linkages are especially relevant for the creation of an integrated video banking service, in which customers are able to execute financial transactions (e.g. transfers between accounts, bill payments, securities trading) as well as teleshopping and other forms of on-line transactions. In short, linkages with new technology suppliers, competitors and transactional service firms are conducive to innovation. We hypothesize that:

> *Hypothesis 3: the more that banks have developed interfirm linkages with firms from computer, telecommunications, stock brokerage, insurance and other transactional providers, the more likely they will venture into the video banking services.*

In the research reported, we tested these hypotheses while holding certain company and industry attributes constant.

RESEARCH DESIGN

Sample and data collection

Our research is based on a sample of 152 of the largest 300 banks in the United States, covering an 11-year period, 1977–87. The original listing was obtained from the *American Banker* (1987). The 152 banks were 'at risk' in adopting video banking. The other banks had to be deleted because of insufficient data, because they were private or because they had been taken over by foreign banks. Of the total *American Banker* listing, 53 actually did adopt the new technology. Forty-nine of the subset of 152 are known to have introduced video banking services in the period 1980–87. They are slightly bigger than the excluded banks. Typically, the included banks are also firms whose records are better accessible and which still existed in 1988.

Financial data of the firms were collected from their annual reports and from *Moody's Bank & Finance Manual* (published annually), while the remaining missing data were furnished by banks. Banks that had introduced video banking are identified from the videotex directory (Arlen Communication, Inc., 1985), the 1985/1986 Directory of Electronic Funds Transfer, and the *American Banker*'s surveys (1985–87).

We collected data about innovation activities and interfirm linkages from secondary, public sources, as they are readily available. The criteria for selecting the information were: (1) the information must contain multiple years of observation and (2) it must contain data from sources relevant for banks (e.g. *American Bankers*, *Wall Street Journal*), computers and telecommunications (e.g. *Computer World*). The only data base that met these criteria was the Predicast Index on U.S. Corporations. We found, however, that the Index was biased toward big firms. The correlation between company size (log asset) and the number of news entries reported in the index is 0.74. We were, therefore, careful to control the possible confounding effect of size. For a review on the benefits and disadvantages of using the Predicast Index in general, see Hladik (1985).

Model specification

The study seeks to identify the role of firms' past experience in technological endeavors and interfirm linkages in predicting their propensity to implement a certain innovation, namely, video-banking services. This study centers on a dichotomous dependent variable: whether or not a firm employs the video-banking services. To test the hypotheses, we can construe the problem as predicting a single-event history.

In the present design, adopting banks are compared with non-adopting banks on the basis of a number of attributes; i.e. the study has many of the features of a case-control design. Such designs are common in research on lung cancer, toxic shock syndrome and epidemiological investigations on rare outcomes.

Unlike the cohort design, the case control study traces effects to antecedent conditions (Anderson, *et al.*, 1980; Schlesselman, 1982). Units with the variable of interest and those without are compared with respect to the hypothesized explanatory variables. In contrast, in the cohort design, the research proceeds from cause to effect. A simple random sample, or a stratified sample of units, is selected and classified according to its exposure to the hypothesized independent variables. The dependent variables are measured and the exposed vs. unexposed units are compared on the basis of this variable (Schlesselman, 1982).

The case-control design is highly appropriate for innovation adoption studies, since adoptions in a particular year are comparatively rare. In a cohort study, a stratified sample of banks would be selected with the strata based on the hypothesized independent variables. Afterwards, data would be collected on whether or not videotex was adopted. Obviously, such a design would require a large data base to possess enough adoption events. The case-control design requires fewer firms. There is no sampling procedure with the intent to ascertain precise population estimates. In the present study, banks are selected on the basis of whether or not they adopted video banking, together with the collecting of relevant independent variables. Adopters are then compared with non-adopters.

Most of our explanatory variables are time-dependent. The use of discrete-time event history analysis is therefore preferable (see Allison, 1984, for a fuller discussion on the conditions required to employ the method). The model, which uses the logistic regression method, is specified as:

$$\text{Log } P/(1-P) = B_0 + \Sigma\, B_i(t),$$

where P is the probability that a firm has the event, B_0 is the intercept, and $B_i(t)$'s are the parameter estimates of the covariates (i.e. the time-varying independent variables). Estimates of parameter B are obtained from the maximum likelihood method. The approach of discrete-time method is to pool and treat the longitudinal data as cross sectional (Allison, 1984). A bank will contribute firm years in proportion to the timing of adoption; if the adoption takes place in year one, one firm year is included in the analysis, and at year two, two firm years, and so on. Non-adopting firms contribute 7 years—the length of the window. To identify the effect of calendar time (year), a set of $(n-1)$ dummy variables are entered into the model, where n reflects the number of years of observations.

Measurement

The main independent variables are the accumulation of experience in information technology and in interfirm linkages. Each experience can be counted, and cumulatively they amount to the magnitude of innovation-relevant know-how. They can also be decomposed into distinctive sets of experiences; for example, hardware, software, telecommunications, joint venture, or M&A. *Information technology* in the banking sector consists of back-office automation and transactional-oriented technology. The first includes computer technology (e.g. installation of on-line terminals for tellers and platform personnel, departmental computing, branch system integration and software upgrades) and telecommunication technology (e.g. the use of satellite and fibre optic networks). Transactional technology is categorized further into ATM networks (e.g. introduction of proprietary ATM networks, ATM for the blind), point of sales systems (e.g. purchase through debit card in supermarkets, gas stations and national retailer networks), home banking services (e.g. bank by phone for bill payments and transfer between accounts) and corporate electronic banking (e.g. electronic cash management and clearing houses).

Additionally, the firm's experience in information technology is measured by two indicators: (1) its investment expenditure in systems and equipment (measured as the percentage of capital spending in equipment to asset) and (2) by a productivity efficiency index (measured as the ratio of interest revenue to non-interest expenses, consisting of equipment and personnel expenses). Naturally, this index is also sensitive to other factors, particularly those residing in the environment, but is often used in the banking community to gauge the productivity of equipment outlays. While the *Predicast* based measure can be interpreted as 'learning by doing,' these two financially derived measures of capital investments approximate what might be called 'learning by using.' Both types of learning are assumed to foster strategic readiness to innovate in certain technological directions.

Interfirm linkages include joint ventures, licensing or contracting the rights to use, produce or market certain products, systems or services without transferring the ownership rights (e.g. several banks licensed Chemical's Pronto video-banking system), marketing agreements (e.g. BancOne agreed to market Manufacturer Hanover's cash management), R&D agreements (e.g. Citicorp and its partners contracted David Sarnoff Laboratories of RCA to develop a video banking software), and supply agreements (e.g. a bank contracts Dow Jones to supply financial data). These interfirm linkages are coded further by the nature of the partner's business (e.g. computer, telecommunications, banks, other financial services, publishing, retailers, or other transactional providers), and whether the arrangement involves various kinds of 'transfers' of technology.

Parenthetically, it should be noted that the inclusion of a variable measuring interfirm linkages among the banks themselves serves to highlight a unique feature of the banking industry itself. Some firms are active in financial networking, others with firms providing dissimilar financial services such as insurance and brokerage. Inclusion of such variables is highly appropriate in industries whose service delivery entails a great deal of interfirm coordination.

In our coding, a bank was assigned one point for each of the above categories whenever it generated an event reported in the *Predicast Index*. The score is the cumulative number of events for each category recorded since 1977, our starting year of observation. The final score for each bank is the cumulative number of events up to the point of adoption. Events were classified as technological or interfirm, where these categories were broken down further in certain subcategories. For example, technological events could further be classified as ATMs, point of sales, credit card, debit card, or bank by phone. Networking events were further partitioned into internal development, licensing, joint ventures or mergers and acquisitions. All events, which are pertinent to a bank's history were obtained from the *Predicast Index* (1977–88).

The *Predicast* volumes provide the titles of articles which have appeared in a variety of media. The items therein were treated as information on a particular bank's relevant experiences or activities, and could be broken down in terms of different types of technology (e.g. credit card, point of sales, ATM, corporate and consumer video banking), type of exchange relationship (e.g. joint venture, licensing agreement or acquisition vs. internal development),

and type of partners (hardware, software, telecommunications, banks, and other financial institutions such as brokerage houses and insurance firms, merchandizing, and newspaper organizations). The source was also used to count the frequency of administrative innovations. These included reorganizations of organization design, compensation systems, sales networks, coordination of services, and personnel training programs. These represent elements of the firm's history, which encompasses a string of experiences with projects, ventures, interfirm networks, and so on, leading up to other related innovations.

Examples of *Predicast* entries are:

> 'Reorganization to form community banking and national consumer sectors' (administrative innovation); 'To use artificial intelligence for foreign exchange trading' (technological innovation-software); 'To jointly form Fleet/Norstar Financial with Fleet Financial for $1.3bln' (interorganizational-banks); 'BancOne jointly develops with E.D.S. video software' (interorganizational-telecommunications).

These entries represented a direct 'translation' of experiences, and were counted to arrive at cumulative scores. No attempt was made to weigh them, nor did we attempt to break them down further. As reported elsewhere (Pennings and Harianto, 1991), triangulation procedures showed that the *Predicast*-based measures have reasonable degrees of validity and reliability.

A coding scheme was developed to classify the experiences in the pertinent categories; it reflects the previously mentioned requirement of deducing the content of the blended technologies and interfirm networking. Within the class of technological experiences, the coding is mutually exclusive: entry into one category precludes entry into others. In the case of interorganizational linkages, however, an occurrence of technical projects employing interfirm arrangements (e.g. 'BancOne jointly develops with E.D.S. video software') should be coded as both a technological experience and as an interorganizational linkage. All interorganizational linkages up to the year of adoption or the year of right censoring (i.e. 1988) yielded a networking score, which can be decomposed into sepcific types of linkages. These cumulative linkages can be examined as a time dependent covariate of innovation. The predictive power of interfirm linkages with various types of firms—as stipulated in Hypothesis 3—can thus be examined. Particularly important is the distinction between linkages that foster acquisition of extramural skills vs. spillovers that originate from competing financial institutions.[1]

The dependent variable is the adoption event. The firms received a score of 1 if they adopted video banking during the period 1981–87, and 0 otherwise. The very first adoption took place in 1981, rendering the data set left censored at this year. The data are right censored up to the point of the study, 1988.

The list of video banking adoptions was obtained from the Arlen Communication Inc. (1985) Videotex Directory, the 1985/1986 Retail Electronic Fund Transfer Directory, and the *American Banker* surveys (1985–87). This collection was a trial and error process, working backwards and forwards, checking entries in different publications against one another. Several listings of commercial banks, together with listings of video banking adopters, led to the creation of a file of banks, including most (49 out of 53) that adopted the innovation.

While testing the hypotheses on innovation diffusion, we control for a number of firm and environment attributes. Firm variables include size, return on assets. Industry attributes include demand, number of competitors and degree of 'shake-out.' Finally, the study controls for 'administrative' or non-technical innovations. These innovations are construed as mirroring a firm's general proclivity to innovate and should be held constant when assessing the effects of a specific set of experiences upon subsequent innovations (Nord and Tucker, 1987). Table I provides a condensed description of all the independent variables in the study.

Equipped with 11 years of data on the banks' technological experiences and successive webs of interfirm relationships, we are now in a position to present some findings on the incidence of video banking. Since we can decompose these covariates into more specific categories, we can also indicate what types of experiences and which classes of interfirm linkages are most conducive for its adoption.

[1] A copy of the coding scheme is available on request from the authors.

Table 1. Summary independent variables, their measurement and sources

Variable	Measurement
Technological experience:	
1. Cumulative experience, Information technology	Cumulative number of events involving all types of hardware, software or telecommunications, 1977-to-date, (Predicast)
2. Cumulative experience, back-office technology	Cumulative number of automation projects in data processing, 1977-to-date (Predicast)
3. Cumulative experience, systems and equipments	Cumulative number of events involving ATM, credit, debit cards, POS, and electronic fund transfer, 1977-to-date (Predicast)
4. Productivity index of systems and equipment	Net income/(equipment, systems & personnel expenses); 3-year average (annual reports)
5. Investments systems and equipment	Total $ investment in systems and equipment/company asset; 3-year average (annual reports)
Networking:	
6. Cumulative linkages, interorganizational	Cumulative number of interfirm arrangements including joint ventures, licensing agreements, turn-key contracts and mergers and acquisition, 1977-to-date (Predicast)
7. Proportion of linkages for technological purposes	Cumulative number of links for technological innovations/total number of cumulative links, 1977-to-date (Predicast)
8. Cumulative linkages with computer and telecommunictions firms	Cumulative number of interfirm arrangements with information technology firms, 1977-to-date (Predicast)
9. Cumulative linkages with other financial institutions	Cumulative number of interfirm arrangements involving banks and other financial services firms, 1977-to-date (Predicast)
10. Cumulative linkages with complementary service providers	Cumulative number interfirm arrangements, with retailers, publishers and data base providers, 1977-to-date (Predicast)
Control variables—company attributes	
11. Cumulative experiences, administrative innovation	Cumulative number of sales, personnel, and general administrative innovations, 1977-to-date (Predicast)
12. Company size	Log $ asset (annual reports, Moody's)
13. Return on equity	Net income/equity (3-year average) (annual reports, or Moody's)
14. Cash flow	(Net income + depreciation + provision for loan losses)/Asset (annual reports, or Moody's)
15. Consumer business	$ Consumer loans/$ total loans (annual reports, or Moody's)
Control variables—industry attributes	
16. Size of consumer demand	Log ($ consumer loans in the state) (FDIC)
17. Growth of consumer demand	($ Consumer loans in the state, this year)/ ($ Consumer loans, last year) (FDIC)
18. Number of banks in the state	Log (number of banks) (FDIC)
19. Mortality index	(Number of banks, this year—number of banks, last year)/(number of banks, this year) (FDIC)

Table 2. Distribution of banks venturing into video banking services

Total	81	82	83	84	85	86	87	
Internal developments	2	3	1	4	4	3	2	19
Licensing/other agreements	1	2	2	11	1	6	1	24
Joint ventures	0	0	1	1	4	0	0	6
Total	3	5	4	16	9	9	3	49

RESULTS

Tables 2–6 report the results of this research. Table 2 shows the annual distribution of the numbers of banks introducing video banking services. Out of 49 ventures, 19 were internal development ventures, 24 involved licensing or other contractual agreements, and 6 were accomplished through joint venturing. One bank got into the service because it acquired a bank that had already introduced the service. There were 22 ventures with limited video banking services, compared to 27 involving integrated videotex services. The distribution of events over time has an inverted-U shape. In the time window 1980–88, there was a rapid growth in the hazard rate, which can be defined as the ratio of the number of 'events'—banks adopting videotex—to the number of uncensored observations. This rate was reaching its peak in 1985, after which it declined toward zero in 1988. The years 1984–85 evoke the impression of a bandwagon, in which numerous banks are mimicking their trend setters; video banking is another expression of 'institutional isomorphism' (DiMaggio and Powell, 1983).

Descriptive statistics about the video banking ventures and the independent variables are shown in Table 3. From Table 4, it appears that five independent variables are highly intercorrelated. Since a large number of observations (pooled data) are involved, a high level of significance obtains at a relatively low correlation coefficient.

Tables 5 and 6 report the results of the logistic regressions, taking care of the multicollinearity problems. The two tables are very significant in terms of their goodness of fit to the overall models, as indicated by their likelihood ratio or chi-square statistic.

Table 5 provides four different models. Models 5.1 and 5.2 are equivalent, except that in 5.1 the dummy variables corresponding to the 7-year time frame were excluded. A comparison of the two columns suggests that the innovation rate is time dependent. The chi-square statistics which are associated with models 5.1 and 5.2 permit the test of the null hypothesis, which states that the hazard rate does not vary over time, net of other variables. The incremental chi-square is 13.54; since its degrees of freedom are six (equivalent to the number of dummy variables entered into model 5.2), it is significant at the 5 percent level. We need to examine the emergence of each and every innovation, recognizing that they are context specific. If and when such research accumulates, we may then broaden technological innovation diffusion models. Since interfirm linkages and technological experiences are highly intercorrelated ($r = 0.76$), they are entered alternately in the model, to become Models 5.3 and 5.4.

The results confirm the first and third hypotheses that cumulative experiences in technology and in interfirm linkages are significantly conducive to the introduction of video banking services. In contrast, two variables, the productivity index and investment in systems and equipment, have no significant effect (Hypothesis 2). Technological experiences and interfirm linkages 'compete' in explaining the probability of the event. Exclusion of either variable renders the other highly significant, as Models 5.3 and 5.4 indicate. Of course, this effect of multicollinearity would not have been discernable if we had only supplied Model 5.2. If the variables are entered jointly, the interfirm linkages variable is the most prominent and highly significant (Model 5.2). In view of the fact that many technological activities entail some form of networking, it should not be surprising that technologically active firms also figure prominently in interorganizational strategies.[2]

[2] A collinearity diagnosis, yielding 'variance-decomposition proportions' (Belsley, Kuh and Welsch, 1980), revealed that technological experience was the only variable whose 'tolerance' remained below the 0.2 level (where this level is deemed to be minimally acceptable). The variable had a tolerance level of 0.17, and a variance inflation of 5.71.

Table 3. Means and standard deviation of independent variables

Variable	Mean	S.D.
Cumulative experience, information technology	0.688	1.643
Cumulative exp., back-office technology	0.222	0.792
Cumulative exp., transaction technology	0.354	0.885
Productivity index, systems equipments	3.446	1.040
Investment systems & equipments	0.344	0.192
Cumulative links, interorganizational	0.447	1.017
Cumulative linkages computer & telecomm.	0.037	0.223
Cumulative linkages, retailers & publishers	0.028	0.185
Cumulative linkages, fin. institutions	0.359	0.819
Proportion of interorganizational linkages for technological innovations	0.013	0.095
Cumulative experience, administrative innovations	0.968	1.807
Log assets in ($ millions)	3.648	0.438
Return on equity, 3-year average (%)	12.645	4.842
Cash flow (%)	1.405	0.732
Consumer business (%)	0.218	0.106
Demand of size, consumer banking ($ Billions)	3.691	0.443
Demand growth, 3-year average (%)	9.797	4.682
Number of banks in the state (Log)	2.333	0.467
Mortality index (%)	−1.035	5.610

Table 6 presents the results for a more disaggregate level of interorganizational experiences. These results show which type of interfirm experiences are most conducive to innovation. Various types of technological experiences are also included in the model. Experiences have been partitioned into specific categories. It is not merely the *amount*, but the *nature* of the experiences, which is crucial. The component technological experiences are comparatively insignificant. In contrast, the results provide detailed information on the third hypothesis, particularly that experiences with computer firms (hardware and software), are most conducive to the introduction of video banking services. Linkages with telecommunication firms, or with retailers, publishing houses and the like, have no significant effect. Linkages with other commercial banks are significant—a striking result. It should be noted that some of these strategic alliances were founded for technological reasons (e.g. licensing Chemical's Pronto systems, the Video Financial Service joint venture). In short, among these disaggregate effects, those involving interfirm conduct appear to be most conducive to technological innovation, while interorganizational relationships contribute to the diffusion of innovation.

The significance of company size is consistent with Bantel and Jackson's (1989) study. It is the only company attribute which predicts the odds of entering the videotex industry. The industry attributes have no significant effect, although one variable, size of consumer demand, comes close to being significant.

In Tables 5 and 6, the dummy variables corresponding to the years 1984 and 1985 (particularly 1984) appear significant. The effect of the year 1984 can be attributed to the Federal Reserve Board's decision allowing commercial banks (in this case, Citicorp) to engage in full-fledged data processing services. During the period 1984–85, there were 15 banks that licensed the Automatic Data Processing's 'Home Banking Interchange' systems.

CONCLUSION AND DISCUSSION

This paper has shown that accumulation of information technology experiences and interfirm networking is conducive to innovation. While these two sets of antecedents are correlated, each is significantly related to the propensity to innovate. There is some overlap between information technology experiences and interfirm

Table 4. Correlation coefficients* of the independent variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Productivity index	100																	
2. Investm. syst & eq	−29	100																
3. Admin. innovations	06	−09	100															
4. Tech. experience	09	−07	64	100														
5. Back-office tech.	13	−09	56	87	100													
6. Transaction tech.	03	−05	55	88	55	100												
7. Interorg. linkages	06	−09	55	76	57	76	100											
8. Link comp. & telec.	09	−07	47	66	67	50	50	100										
9. Link retail & publ.	−01	03	20	25	19	23	35	14	100									
10. Link financial firms	02	−09	47	62	42	66	93	28	17	100								
11. Size	31	−14	52	53	45	47	48	32	15	44	100							
12. Return on equity	03	14	−12	−05	−02	−08	−10	−01	01	−08	01	100						
13. Cash flow	−13	06	−01	−01	−04	03	02	00	02	00	−10	25	100					
14. % Consumer loans	−42	20	−17	−14	−14	−12	−13	−11	03	−13	−36	11	10	100				
15. Consumer demand	14	−01	31	22	23	19	25	17	04	25	36	−03	03	−25	100			
16. Growth demand	04	16	−06	−04	−05	−03	−04	−08	−02	−03	−01	24	07	15	−07	100		
17. Number of banks	12	−06	09	01	00	06	09	03	02	09	11	−11	06	−35	53	−27	100	
18. Mortality index	01	03	05	09	09	07	02	04	−04	02	04	06	04	−08	02	19	−00	100

* Decimal points omitted; a coefficient beyond 0.09 is significant at the 0.01 level.

Table 5. Logistic regression results dependent variable: Entering video banking

Variable	Model 5.1	Model 5.2	Model 5.3	Model 5.4
Intercept	−11.392***	−12.316***	−12.752***	−12.553***
	(2.840)	(3.068)	(3.041)	(3.046)
Cum. experience, inf. technology	0.200	0.206*		0.288***
	(0.128)	(0.128)		(0.114)
Cum. interorganizational linkages	0.279**	0.222	0.354***	
	(0.140)	(0.158)	(0.132)	
Proportion of interfirm linkages for technological innovation productivity index, system & equip.	1.5604**	1.897**	2.153***	1.821***
	(0.888)	(0.944)	(0.904)	(0.949)
	−0.214	−0.226	−0.232	0.221
	(0.200)	(0.254)	(0.239)	(0.244)
Investments, system & equipment	−0.233	−0.720	−0.486	−0.959
	(1.093)	(1.068)	(1.092)	
Cum. experience, administrative innov.	−0.185*	−0.166*	−0.085	−0.158
	(0.097)	(0.101)	(0.086)	(0.100)
Company attributes				
Size	1.269**	1.230*	1.403***	1.357***
	(0.560)	(0.584)	(0.572)	(0.578)
Return on equity	−0.003	−0.002	−0.002	−0.006
	(0.040)	(0.040)	(0.039)	(0.039)
Cash flow	0.045	0.048	0.049	0.077
	(0.289)	(0.378)	(0.388)	(0.340)
Consumer business	1.742	1.484	1.508	1.579
	(1.867)	(1.928)	(1.901)	(1.932)
Market attributes				
Size of consumer demand (Log)	0.823*	0.872*	0.923*	0.813
	(0.509)	(0.537)	(0.528)	(0.534)
Growth of consumer demand	0.021	0.034	0.031	0.036
	(0.037)	(0.032)	(0.031)	(0.033)
Number of banks in state	0.196	0.165	0.005	0.222
	(0.474)	(0.481)	(0.466)	(0.480)
Mortality index	0.016	−0.010	−0.007	−0.008
	(0.030)	(0.030)	(0.010)	(0.030)
Year 81 (dummy)		0.218	0.454	0.076
		(1.049)	(1.002)	(1.038)
Year 82 (dummy)		0.743	0.868	0.681
		(0.893)	(0.877)	(0.884)
Year 83 (dummy)		0.856	0.906	0.802
		(0.821)	(0.816)	(0.817)
Year 84 (dummy)		1.913**	1.965***	1.920***
		(0.732)	(0.727)	(0.728)
Year 85 (dummy)		1.340*	1.419*	1.335*
		(0.731)	(0.725)	(0.732)
Year 86 (dummy)		1.148	1.165	1.157
		(0.729)	(0.727)	(0.729)
−2 Log likelihood	318.21	304.68	307.56	306.63
Chi-squared (D.F. = 19)	58.54***	72.07***	69.19***	70.12***
D.F.	14.00	20.00	19.00	19.00
Number of firm years	867.00	867.00	867.00	867.00
Number of adopting banks	49.00	49.00	49.00	49.00

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses.

Table 6. Logistic regression of videotex adoption with technological interorganizational experiences broken down into specific categories

Variable	
Intercept	−12.030***
	(3.135)
Productivity index	−0.284
	(0.255)
Prior investment, systems & equipment (3-yr avg.)	−0.342
	(1.076)
Cum. experience, administrative innovation	−0.152
	(0.111)
Cum. experience, office technology	0.362
	(0.236)
Cum. experience, transaction technology	−0.409*
	(0.225)
Cum. linkages with telecomm. firms	0.773
	(1.045)
Cum. linkages with computer hardware firms	2.755***
	(1.092)
Cum. linkages with software houses	1.526**
	(0.694)
Cum. linkages with transact. providers	0.791
	(0.547)
Cum. linkages with other banks and financial services firms	0.420**
	(0.198)
Year 81 (dummy)	0.026
	(1.087)
Year 82 (dummy)	0.579
	(0.908)
Year 83 (dummy)	0.691
	(0.829)
Year 84 (dummy)	1.773**
	(0.740)
Year 85 (dummy)	1.256*
	(0.740)
Year 86 (dummy)	1.273*
	(0.737)
Control variables:	
Log asset	1.475***
	(0.607)
Return on equity	−0.007
	(0.042)
Cash flow	0.124
	(0.284)
Consumer loan	1.332
	(1.919)
Industry attributes:	
Size of demand, consumer loan (log)	0.658
	(0.553)
Annual growth of demand	0.031
	(0.031)
Number of banks in the state	0.124
	(0.447)
Mortality index	0.000
	(0.031)
−2 log likelihood	297.97
Chi-squared (D.F. = 19)	78.79***
D.F.	24.00
Number of firm years	867.00
Number of adopting banks	49.00

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses.

linkages because some linkages are formed for the purpose of implementing technological investments. The greater a bank's inclination to network with information technology firms, the greater the probability it will adopt video banking. When we partition linkages into specific categories, as was done in Table 6, the results suggest spillovers from competing organizations, as well as procurement of computer hardware and software technology. These are among the most important linkages in accounting for the incidence of video banking.

Therefore, both internal and extramural skills are crucial for innovation. A bank's distinctive competence derives not only from internal experiences; home grown skills improve its capacity to absorb external skills, which are presumably being tapped when the bank is heavily involved in networking with information technology firms. Accumulating technological skills and external networks are crucial events in a bank's history, if we make an attempt to explain their current innovative conduct. Viewing innovation as following from a chain of events enriches our understanding about the process of innovation itself and hence reveals the merit of event-history analysis.

The results support the core elements of the theory as specified in Hypotheses 1 and 3. The cumulative experience in video banking-relevant technologies diminishes the distance between the skills already residing in the firm and extramural skills which are combined so as to enable the implementation of this innovation. Of course, this thinking is highly consistent with the Schumpeterean notion that innovation essentially represents the recombination of existing know-how. In the present case, this know-how involves multiple industries, necessitating the extension of a firm's boundaries into other industries.

The single, most striking finding of this study was the strong effect of the proportion of technological linkages. The more a firm commits itself to technological networking, the greater its propensity to innovate. Networking and technological experiences are correlated and are therefore somewhat statistically redundant. Both variables are predictive of the innovation event. In their redundancy, these variables compete in accounting for the bank's probability to innovate. The prominence of technological networking in all regression models, however, is a testimony to our position that interfirm linking is an important precursor to innovation.

It is not clear why Hypothesis 2 failed to receive support. As was indicated, the two pertinent variables convey a sense of 'learning by doing,' consistent with the argument of Lieberman (1984). The productivity index also incorporates information not germane to information technology. Similarly, investment in systems and equipment included not only computer or telecommunications technology, but also other investments—for example, typewriters and office furniture. Currently available data sources do not allow the partitioning that better fits the needs of this research. We stress, however, that in the current study, a learning indicator has been used which was far more specific than the one used by Lieberman (1984).

The present study is restricted in that consumer attributes were not included in the model. The size of demand approximated conventional significance levels, suggesting the presence of 'market pull.' Several other, more specific attributes were included, but they might not fully capture consumers' attitudes toward electronic payment systems in general. Other studies should develop measures which are better attuned to consumer attitudes and opinions.

Issues of sector and innovation specific findings

The role of conventional market structure variables did not surface as prominently as it might have. Obviously, this study should be replicated on other innovations, involving firms in different industries. Ideally, such industries should differ on boundary permeability and degree of interfirm partnering, or with respect to some modal forms of strategic alliances such as joint ventures, licensing agreements, turnkey contracts and minority interests, and the types of innovations around which they evolve. Such a comparison would permit a detailed multilevel study, tracing the diffusion of innovation to technological and interfirm experiences and market structure variables, as well as varying degrees of interindustry interdependencies (Pennings, 1981). Some of the control variables such as changes in demand, concentration ratio and amount of shake-outs could figure more prominently in the hypothesis testing—particularly if the research is extended to other settings. In some ways, the findings of

this study inevitably reflect the uniqueness of the financial services industry.

The sudden emergence of converging technological trends in the banking industry entails a quasi-experiment providing unique opportunities for hypothesis testing. Industry studies conducted in other settings should reveal how far the present results are idiosyncratic to the financial services industry. Likewise, studies in Europe and Pacific Basin countries might disclose to what extent this research is U.S. biased (compare Grant, Jammine and Thomas, 1989, who raise a similar issue with respect to strategic diversification studies). It should also be borne in mind that the banking industry is not the only one being inundated with information technology. Transportation, entertainment and watch and toy industries, to name a few, are likewise witnessing an increased dependence on technology which traditionally is not theirs. The drastic transformation of those industries creates opportunities for corporate entrepreneurship. We are witnessing the creation of various interfirm structures to harbor such entrepreneurial activities. They should be studied in order to understand how firms in a given industry succeed in absorbing the know-how which originally was largely alien. This study of financial services firms is illustrative of the sort of behaviors that any firm may display under conditions of increased interindustry interdependence. What sets banks apart, however, is that their service delivery often requires interfirm coordination. They resemble therefore such sectors as airlines, telephone companies and health care providers. As we have seen, competitor linkages are also conducive to innovation. It is therefore obvious that replications should consider these sectors in the first place.

Studies on the present level of analysis uncover how firm-specific traits provide ingredients for industry and interindustry dynamics which population level or input-output tables cannot provide. As Astley (1985) has suggested, research should move from the level of industry to what they call the population level. However, the strategic implications of interindustry interdependencies should not only be inferred from input-output R&D, as Scherer (1982) suggested, or value added flows, but also from the trends in interfirm exchanges which firms maintain in order to expand the so-called 'visible hand' (Chandler, 1976). However, it is not yet evident how various interfirm structures stabilize knowledge flows among industries.

Significantly, it should be pointed out that this research did not attempt to account for the incidence of video banking. We relied on a variant of the case control method (Schlesselman, 1982) that compares adopters vs. non-adopters. The intercept in this model would not accurately reflect the incidence of video banking in the U.S. The estimate of the incidence, the intercept, is biased in relation to the proportion of adopters vs. non-adopters. The covariates in the study, however, are not affected by the retrospective sampling procedure. These estimates were central to the present study.

A 'failed' innovation

Much can be said about successful vs. failed innovations. It remains difficult to specify what is meant by failure. Recent experimentation, for example with CompuServe and Prodigy, points to wider consumer acceptance of video banking in the U.S. Prodigy has over one million subscribers now. Its French version, Minitel, has been an astounding success. Compared with Europe, the U.S. banking and telecommunications industry is still heavily regulated. Regulation has precluded local telephone companies or long distance carriers from joining the videotex industry. Even an obvious service as on-line directory assistance is prohibited. Deregulation could eliminate some of the barriers for diffusion, however (Aumente, 1987). Also, as shown in Table 1, there are different modes of entry into the service (i.e. internal development, licensing, joint venturing and acquisition). They dictate entry strategies with different technological and marketing risks.

Any innovative effort entails strategic risks. Ideally, a firm wants to enter a market with the right (or 'dominant') design. However, without careful planning, two types of strategic errors can be committed. A firm may enter *too early* when design requirements are still in an experimental stage and the choice results in an unsuccessful design. This 'first mover' dilemma represents a development risk; although, since R&D expenditures and capital intensity in the banking sector are comparatively minor, this risk is rather small. It was, however, a significant issue in the early eighties when several expensive,

but ill-conceived, video banking adoptions such as Chemical's Pronto, 'crashed.' A firm might also enter *too late*, when the product or service requirements have become known and have found their way into a dominant design. This dilemma amounts more to a marketing risk. This error is serious because the laggard will face an uphill battle against the adopter who enters with the right design at the right time, i.e. who committed neither of the two errors. Minitel, the French videotex service has become a dominant design, while Prodigy and CompuServe are still exploring whether any one of them, or a laughing third might become the U.S. dominant design.

In the service sector where strategic mimicking of services seems easy and fast, technology-based innovations appear to be an exception in that implementation takes a long time. A firm needs to commit resources that permit it to respond to new technological developments. At the same time, and even more so, the firm requires the flexibility and market intelligence to market new services at a strategically opportune time. When new technology continues to diffuse into the banking sector, the banks should be prepared to respond technologically and commercially.

It is important, therefore, not to dismiss videotex in the U.S. as an outright failure because its learning and networking benefits cannot be gauged at the present time. Some of these benefits may be quite intangible. Videotex enhances a bank's absorptive capacity in information technology—a technology which is so critical for this sector. For managers, it remains crucial not to dismiss failed innovations as a lost cause but rather to justify adoption as preserving their competitive edge in building and acquiring new skills. Regulations may change, thus altering a firm's strategic contingencies. New technologies will further enter the banking sector, creating unforeseen strategic contingencies. Finally, as we have shown, the market of banking services has become volatile. Responding to volatility requires that banks do not take their environment for granted.

Indeed, many firms are continuously engaged in some form of corporate entrepreneurship to develop and promote their capacity for future activity. Since such activities entail risk of failure, the crucial element of managerial responsibility is to gauge the trade-offs between the acceptable risk and the growth of future resources. Ultimately, the health of any firm is optimal when it finds a balance between capitalization of existing resources and the formation of new ones (Penrose, 1959). It may be difficult to delineate an optimal trade-off. Yet, this study suggests that firms continuously add know-how to their existing pool of skills and promote their readiness to venture into future projects. Furthermore, this accumulation of skills is not restricted to process and product skills. This study shows that by 'investing' in interfirm contacts, companies broaden their exposure to other industries. This exposure furnishes important strategic advantages, and endows them with the adaptiveness that is particularly needed at the present time. While this has been a study on banking, it presents also important implications for all those industries, whose core skills become blended with know-how that is not traditionally theirs.

ACKNOWLEDGEMENTS

This research was supported by National Science Foundation grant SES-8709674 (Johannes M. Pennings Principal Investigator) and by the Jones Center of the Wharton School. We appreciate the comments of Eric Abrahamson, Paul Allison, Graham Astley, Bob Drazin and Larry Robbins.

REFERENCES

Abernathy, W. J. and J. M. Utterback. 'Patterns of industrial innovation', *Technology Review*, **80**, 1978, pp. 40–47.

Abrahamson, E. and L. Rosenkopf, 'When do bandwagon diffusions roll? How far do they go? and When do they roll backwards: A computer simulation', *Academy of Management Best Paper Proceedings*, 1990.

Allison, P. D. *Event History Analysis*, Sage, Beverly Hills, CA, 1984.

American Banker. *Annual Survey*, The American Banker, Washington, DC, 1977–1988.

Amit, R., J. Livnat and P. Zarowin, 'The mode of corporate diversification: Internal modes versus acquisition', *Managerial and Decision Economics*, **10**, 1989, pp. 89–100.

Anderson, A., A. Auquir, W. W. Hauck and D. Oakes, *Statistical Methods for Comparative Studies*, Wiley, New York, 1980.

Arlen Communication, *Videotex Directory*, Arlen Communication, Inc., Washington, DC, 1985.

Arrow, K. J. 'The economic implications of learning

by doing', *Review of Economic Studies*, **29**, 1962, pp. 155–173.

Astley, G. T. 'The two ecologies: Population and community perspectives on organizational evolution', *Administrative Science Quarterly*, 1985, pp. 224–262.

Aumente, J. *New Electronic Pathways*, Sage, Beverly Hills, CA, 1987.

Bantel, K. and S. J. Jackson. 'Top management and innovation in banking: Does the composition of top management teams make a difference?' *Strategic Management Journal*, Special Issue, 1989, pp. 107–124.

Belsley, D. A., E. Kuh and R. E. Welch, *Regression Diagnostics*, Wiley, New York, 1980.

Braun, E. and S. MacDonald, *Revolution in Miniature: The History and Impact of Semiconductor Electronics*, 2nd Edn. Cambridge University Press, New York, 1982.

Chandler, A. *The Visible Hand*, Belknap, Cambridge, MA, 1976.

Cohen, W. M. and D. A. Levinthal. 'Innovation and learning: The two faces of R&D', *Economic Journal*, **99**, 1989, pp. 569–596.

Compaine, B. M. *Understanding New Media*, Ballinger, Cambridge, MA, 1984.

Cyert, R. M. and J. G. March. *A Behavioral Theory of the Firm*, Prentice Hall, Englewood Cliffs, NJ, 1963.

DiMaggio, P. and W. W. Powell. 'The iron-cage revisited: Institutional isomorphism and collective rationality in organizational fields', *American Sociological Review*, **43**, 1983, pp. 147–160.

Directory of Electronic Fund Transfer, *Directory of Electronic Fund Transfer*, EFT, New York, 1986.

Economist, The, 'Survey on banking', March 17, 1989.

Enright, M. J. 'Geographic concentration, vertical structure and innovation'. Working Paper, Harvard University, Cambridge, MA, 1989.

Federal Deposit and Insurance Commission. *Bank Operating Statistics*, FDIC, Washington, DC, 1976–1983.

Federal Deposit and Insurance Commission. *Statistics on Banking*, FDIC, Washington, DC, 1985–1987.

Grant, R. M., A. P. Jammine and H. Thomas. 'Diversity, diversification, and profitability among British manufacturing companies, 1972–1984', *Academy of Management Journal*, **31**, 1988, pp. 771–801.

Harianto, F. and J. M. Pennings. 'Technological innovation through interfirm linkage'. In L. Gomez-Mejia and M. W. Lawless (eds.) *Managing The High-Technology Firm*, JAI Press, Greenwich, CT, 1990, pp. 15–42.

Hladik, K. J. *International Joint Venture: An Economic Analysis of U.S.-Foreign Business Partnerships*. Lexington Books, Lexington, MA, 1985.

Kazanjian, R. and R. D. Drazin. 'Implementing internal diversification', *Academy of Management Review*, **12**, 1987, pp. 342–354.

Kogut, B. 'Joint ventures: Theoretical and empirical perspectives', *Strategic Management Journal*, **9**, 1988, pp. 319–332.

Lieberman, M. B. 'The learning curve and pricing in the chemical processing industries', *Rand Journal of Economics*, **15**, 1984, pp. 213–228.

Lieberman, M. B. and D. B. Montgomery, 'First mover advantage', *Strategic Management Journal*, **9**, 1988, pp. 41–58.

Mansfield, E. 'Size of firm, market structure, and innovation', *Journal of Political Economy*, **71**, 1963, pp. 477–485.

Mohr, L. B. *Explaining Organizational Behavior*, Jossey Bass, San Francisco, CA, 1982.

Nord, W. R. and S. Tucker. *Implementing Routine and Radical Innovation*, Lexington Books, Lexington, MA, 1987.

Normann, R. 'Organizational innovativeness: Product variation and reorientation', *Administrative Science Quarterly*, **16**, 1971, pp. 203–215.

Nelson, R. R. and S. G. Winter. *An Evolutionary Theory of Economic Change*, Belknap Press and Harvard University Press, Cambridge, MA, 1982.

Office of Technology Assessment, Congress of the United States. *Effects of Information Technology on Financial Service Systems*, U.S. Government Printing Office, Washington, DC, 1984.

Pennings, J. M. 'Strategically interdependent organizations'. In P. C. Nystrom and W. H. Starbuck (eds.) *Handbook of Organization Design*, Vol I, Oxford University Press, New York, 1981, pp. 433–455.

Pennings, J. M. 'On the nature of new technology as organizational innovation'. In J. M. Pennings and A. Buitendam (eds.) *New Technology as Organizational Innovation*, Ballinger, Cambridge, MA, 1987, pp. 3–12.

Pennings, J. M. and F. Harianto. 'Technological innovation and organizational form'. Working Paper, The Jones Center of the Wharton School at the University of Pennsylvania, 1991.

Penrose, E. *The Theory of the Growth of the Firm*, Wiley, New York, 1959.

Predicast. *Index of American Business*, Predicast, New York, 1978–1988.

Revell, J. R. S. *Banking and Electronic Fund Transfers*. Organization for Economic Cooperation and Development, Paris, 1983.

Rosenberg, N. *Inside the Black Box: Technology and Economics*. Cambridge University Press, New York, 1982.

Rumelt, R. *Strategy, Structure and Economic Performance*, Division of Research, Graduate School of Business Administration, Harvard University, Boston, MA, 1974.

Scherer, F. M. 'Inter-industry technology flows in the United States', *Research Policy*, **11**, 1982, pp. 227–245.

Schlesselman, J. J. *Case-Control Studies: Design, Conduct, Analysis*, Oxford University Press, New York, 1982.

Schumpeter, J. A. *The Theory of Economic Development*, Harvard University Press, Cambridge, MA, 1934.

Williamson, O. E. *Markets and Hierarchies*, Free Press, New York, 1975.