Slow and steady wins the race: learning and the innovation process

Thesis

OPEN UNIVERSITY OF THE UNITED KINGDOM

Slow and Steady Wins the Race: Learning and the Innovation Process

Chirag Patel
ESC Rennes, France

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY (Ph.D.)

22 September, 2006

DATE OF SUBMISSION: 25 SEPTEMBER 2006

PREFACE

DECLARATION

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration. It has not been previously submitted for any other degree or qualification either at the Open University, U.K. or any other institution.

STATEMENT OF LENGTH

This dissertation does not exceed the limit of 100,000 words including tables, footnotes, bibliography and appendices, as required by the Open University Research School.

To

Taran

ACKNOWLEDGEMENTS

I am thankful to my wife, Taran, my sister Poonam and her friend Poochi for their support at all levels and at all times during the course of this study.

I am indebted to my supervisor, Dr. Jaideep Prabhu who has guided me at every step: from pointing to the right literature to training me to think like a researcher. His efforts have not only been intellectual but also include great care and concern along the entire course of this study. This combination is rare to find in a supervisor.

I thank my Director of Studies, Dr. Serge Oreal for his moral support. I am also thankful to Dr. Ron Adner and Dr. Nicolas Nicolou for going out of their way to provide helpful comments on this thesis. Further I thank Dr. William Greene, Dr. Pravin Trivedi and Mark Gregory for their willingness to discuss and provide comments on specific aspects of this thesis. All errors and omissions are entirely my own.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CRM: Customer Relationship Management

DV: Dependent Variable

ERP: Enterprise Resource Planning

FDIC: The Federal Deposits Insurance Corporation

GLM: Generalized Linear Model

HTML: Hypertext Media Languages

IT: Information Technology

IV: Independent Variable

OCC: The Office of the Comptroller of Currency

OFX: Open Financial Exchange

OLS: Ordinary Least Square

R&D: Research and Development

SDC: Securities Data Companies

3SLS: Three-stage Least Squares Estimation

XML: Extensive Mark-up Language

ZIP: Zero-inflated Poisson

ZINB: Zero-inflated Negative Binomial

Slow and Steady Wins the Race: Learning and the Innovation Process

Abstract

How should incumbent firms innovate in IT-based services in the long term? Past empirical research and conventional wisdom suggest that firms should be fast during the radical and incremental phase. We challenge this view in the context of the knowledge economy. We contend that incumbent firms can either be fast during the radical phase or during the subsequent incremental phase of the innovation process. We draw on the innovation and organizational learning literature to argue that sequential combination of modes of learning during the innovation process explains this phenomenon.

We show that incumbent firms that learn through the path of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase will be slow at initial radical innovation but fast at subsequent incremental innovations. In contrast, incumbent firms that learn through any other path will be faster at radical innovation but slower at incremental innovations. We study the innovation in IT-based service of online retail banking over nine years (from 1995 to 2003) using archival data. Analysis of a longitudinal data set of 89 incumbent U.S. banks provides evidence for the thesis.

Chapter 1: Introduction

Bancorp South Bank was fast at online transactional banking as compared to many competitors. In mid 1997, Bancorp South started offering basic online transactional banking services like balance inquiry, fund transfer, and bill payment. The key technology underlying these services was the online banking platform. This software was licensed from nFront (Online Banking Report, 1999). Among Bancorp's competitors, JP Morgan Chase bank went online in early 1999, about two years *after* Bancorp South's online banking website. The online banking software had been developed in-house (Online Banking Report, 1999). Had the story ended here, at the early stage of this new product category, one would conclude that Bancorp South bank won the race in developing its online banking website.

However, in the next growth stage after the radical innovation of online banking, JP Morgan Chase bank licensed complementary technologies from nine companies. For example, it licensed technological components for its wireless infrastructure from Tantau software (Bank Systems and Technology, 2001) and technology for internet payroll processing from Powerpay.com (Bank Systems and Technology, 2001). By 2003, JP Morgan Chase had introduced six incremental online banking services. The basic online banking website was developed by introducing incremental services like e-lending, e-brokerage, e-insurance, e-cash management, check image and wireless banking. In contrast, Bancorp South did not license any complementary technologies. It became slow at developing its online banking services. By 2003, Bancorp South had introduced only three incremental online banking services.

This story raises some interesting questions: Despite being fast at developing the radical innovation of online banking, why was Bancorp South bank slow at subsequent incremental innovations? In contrast, JP Morgan Chase had been relatively slow at developing its online banking and yet fast at incremental innovations. Why? Such stories are common in today's knowledge economy[1] which is characterized by information technology (IT)-based services[2] like online banking, online travel agencies, online procurement, online purchase and distribution of digital products like online songs, data analysis software, e-books and others (see Dodge, 2005; Tellis and Golder, 2001). *In general, how should incumbent firms innovate in IT-based services in the long term?* Should these firms focus on being fast initially or does slow and steady win the race in the long term? Can strategies other than being fast initially better explain speed of innovation in the long term? By asking these research questions, we seek to unravel strategies that allow incumbent firms that are slower at initial radical innovation in IT-based services to be faster at subsequent incremental innovations in the long term.

Typically, past literature has failed to unravel the dynamics of competing at innovations over time. Some past literature has focused on studying competition in

[1] Knowledge-based economies are defined as "economies which are directly based on the production, distribution and use of knowledge and information" (OECD, 1996: p7). There are three characteristics of a knowledge economy. First, it emerges from an industrialized economy based on natural resources and labour like the U.S. or the European Union in the early '90's. Second, there is a shift in demand from manufactured goods like cars, planes, electric light, type writers to a predominance of IT-based services like online flight reservations, online banking, online consulting, online casinos, online commerce, across broad sectors of the economy, including manufacturing, communications, trade and services (Dawson et al., 2006; Eathingtion and Swenson, 2002). Third, the shift to IT-based services results in economic prosperity and growth. This is exemplified by the growth in the 90's of the U.S. economy (U.S. Department of Commerce, 2000). Literature also uses other terms like weightless economy (Quah, 1999), new economy, digital economy in referring to this phenomenon.

[2] We define IT-based services as electronic systems that enable electronic commerce transactions and electronic business processes. These electronic systems are composed of codified knowledge in the form of three resources: software resources i.e. information processing instructions, data resources i.e. formal language and network resources like internet, intranet and extranets (O'Brien and Marakas, 2006). Further, the development of these electronic systems requires integration of software with customer information, firm processes and supporting IT infrastructure (Momma, 2000). Hardware like computers, servers and other devices serve as supporting infrastructure for IT-based services (Mesenbourg and Atrostic of the U.S. Census Bureau, 2001). For example, IT-based services like online package tracking services require development of software that records information about the location of the package at regular intervals of time. This software also records customer information associated with the package. Finally, the software is integrated into the source code of a web site and hosted on the internet through servers.

innovating among new entrants and incumbent firms as an outcome at a point in time. Specifically, this research studies competition between new entrants and incumbent firms in being fast during the early stage of a new product category (see Schumpeter, 1934, 1950; Christensen, 1993; Teece, 1986; Tripsas, 1997; Rothaermel, 2001; Hill and Rothaermel, 2003; Ahuja and Lampert, 2001). An example is the competition between new biotechnology companies and incumbent pharmaceutical companies to develop biopharmaceuticals during the mid '70s. In contrast to these studies, we focus on competition between incumbent firms during the early and growth stage of a new IT-based service.

In addition, some past literature studies the positive performance implications of being fast either in the early or the growth stage of a new product category (see Bond and Lean, 1977; Urban et al., 1986; Robinson and Fornell, 1985; Parry and Bass, 1990; Kalyanaram and Urban, 1992; Lieberman and Montgomery, 1988; Kerin et al., 1992; Robinson et al., 1994; Kalyanaram, Robinson and Urban, 1995). We do not challenge the performance benefits of being fast at innovation. Instead we build on recent literature that stresses the importance of performance benefits of being fast specifically during the growth stage (e.g. Jones, 2003; Banbury and Mitchell, 1995). Hence, we ask the research question: How should incumbent firms innovate in IT-based services *in the long term?*

In the past literature, research concludes that firms which are fast at radical innovation in the early stage will be able to develop more incremental innovations over time (Robinson and Fornell, 1985; Robinson, 1988). This research includes only goods from the industrialized economy. Moreover, the conclusion of these studies is widely considered to be applicable to the knowledge economy. This is reflected in popular press which is unanimous about the need to be faster than the competition at radical innovation, specifically in the knowledge economy. A recent article in Business Week (2006) titled

'Speed Demons' focuses on the need of speed in the knowledge economy. This is considered especially true for electronic businesses and has lead to the coining of a new term 'Internet Speed'. Hence, past literature and conventional wisdom suggest that speed at radical innovation is beneficial in the industrialized economy and especially in the knowledge economy. We challenge this view in the context of the knowledge economy. Our thesis is that some incumbent firms that are initially slow at radical innovation in IT-based services can be faster at subsequent incremental innovations than incumbent firms that are initially fast at radical innovation. We explain this by drawing on the literature on organizational learning and innovation.

In the process, we make three contributions to the past literature: First, we view and measure innovation as a dynamic process[3] so as to extend the above mentioned literature on competition in innovating at a point in time. We specify that innovation begins with a radical phase (i.e. the early stage of a new IT-based service category) and is followed by an incremental phase (i.e. the growth stage of a new IT-based service category). This approach allows us to study the development of a single radical innovation during the radical phase and its subsequent incremental development during the incremental phase. In contrast, past literature views innovation as a static event categorized into two types: radical and incremental. Hence, past literature has been restricted to studying competition in innovation as an outcome at a point in time or as two outcomes occurring in different product categories at one point in time. An example of the latter is the literature on ambidextrous firms that compete simultaneously across product categories at the same time (Tushman and O'Reilly III, 1996; Birkinshaw and Gibson, 2004). In contrast to this past literature, we focus on a single IT-based service category and view it dynamically.

[3] Based on existing conceptual and empirical research on the nature of innovation (Tushman and Anderson, 1986; Henderson and Clark, 1990)

Second, we study the context of innovation in IT-based services[4] in the knowledge economy so as to extend the literature on innovating over time that focuses mostly on goods from the industrialized economy. Moreover, the context of knowledge economy is important in today's world because the shift from industrialized to knowledge economy has become an important agenda for advanced economies. This is exemplified by the emerging commitment of economies like the European Union to move towards being a leader in the knowledge economy (European Council, 2000).

The study of competition at innovation over time in the context of IT-based services is also important for academics who have argued that the shift from industrialized to knowledge economy requires an extension of existing approaches to strategy (Lloyd, 2004). Strategies on competing at innovation over time are expected to differ for IT-based services as compared with goods and pure services. This expected shift in strategy is attributed to the knowledge component of IT-based services. This knowledge component differentiates IT-based services from goods and pure services in-terms of their effect on firm strategy, industry applicability and economic changes. From a firm perspective, IT-based services require integration of software with customer information, firm processes and IT infrastructure (Momma, 2000). From an industry perspective, IT-based services can emerge in varied industries, from manufacturing to pure services industries. For example, online retail banking represents a powerful radical innovation in IT-based service for the retail banking services industry (Chandy et al., 2003). Similarly, digital photography represents a powerful radical innovation for the silver halide photography industry (Santi, 2003). Further, from an economic perspective, IT-based services are considered to have

[4] IT-based services enable electronic commerce and electronic business processes by supporting transaction of information. For example, b-to-c, b-to-b, c-to-b and c-to-c transaction of digital products like e-books, music files and games over the internet; or transaction of information like online brokerage services, package tracking services, online news, online consulting, consumer forums, online virtual games, online c-to-c auctions, online flight check-in. IT-based services also include internal firm transaction of information through use of ERP systems, example for managing internal operations like streamlining of procurement processes, conducting and re-engineering production processes, aiding research and development.

challenged conventional economic theory by allowing the co-existence of economic growth and low inflation in the knowledge economy (Greenspan, 1998). These characteristics of IT-based services indicate that they can emerge across varied industries and they have considerably different effects on firms and the economy as compared to goods and pure services. Hence, it is important to study competition at innovation over time in the context of IT-based services.

Third, we take a knowledge-based view (Nonaka 1994; Grant, 1996; Spender, 1996; Winter, 1987) of competition between incumbent firms to innovate IT-based services over time. A comparison of knowledge-based view of the firm with other theories indicates that it can provide insights in the context of innovations (see Foss, 1996). Specifically, we use this theoretical approach to develop arguments based on the path-dependent nature of learning. In so doing, we show that incumbent firms which focus initially on internal learning are slower at radical innovation but faster at subsequent incremental innovations compared to firms that do not focus on internal learning. Hence, we demonstrate that past research that studies the effect of the speed of radical innovation on the speed of incremental innovations has failed to consider the crucial role of learning during the innovation process. This has led to overly simplistic expectations about the positive effect of the initial speed on future speed.

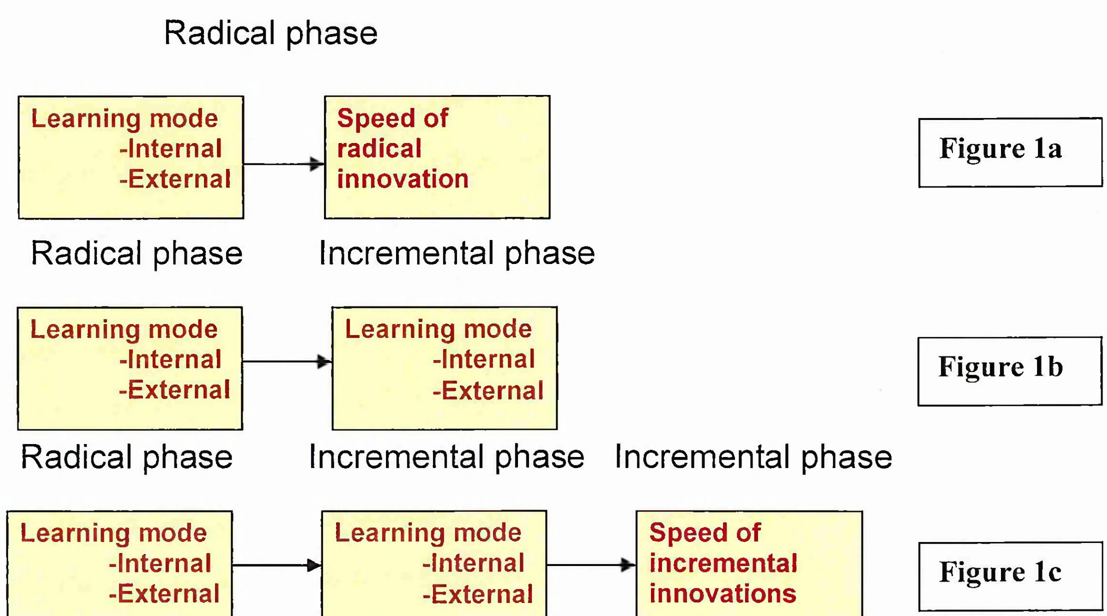
Further, the choice of knowledge-based view as a theoretical approach is crucial in studying the context of innovation in IT-based services. IT-based services differ from goods and pure services in terms of being composed of codified knowledge and requiring integration with customer information, firm processes and supporting IT infrastructure. Hence, a study of innovation in IT-based services is essentially about developing new knowledge. The knowledge-based view of the firm is thus best suited as a theoretical approach to study this context.

In the next section, we present the conceptual framework and discuss the key variables. Then we present arguments to justify our hypotheses on the effects of modes of learning during the radical phase on innovation outcomes over time and on choice of mode of learning during the incremental phase. The following sections describe the empirical context, discuss the models used for testing the hypotheses and present the results. We end with a discussion of the implications and limitations of this research.

Chapter 2: Conceptual Framework and Hypotheses

We draw on the innovation (Tushman and Anderson, 1986; Henderson and Clark, 1990), organizational learning (Cohen and Levinthal, 1990; Prencipe, 1997, 2000) and knowledge-based view of the firm (Grant, 1996; Spender, 1996; Nonaka, 1994; Winter, 1987; Nelson and Winter, 1982) literature to develop the following conceptual framework (see Figure 1). In this framework, we view innovation in IT-based services as a process comprising a radical phase followed by an incremental phase. The radical phase involves the commercialization of the radical innovation while the incremental phase involves the incremental development of the radical innovation, resulting in many incremental innovations over time. Learning during each phase of the innovation process can occur through two modes: internal knowledge creation or external knowledge transfer. Incumbent firms' choice of mode of learning during the radical phase affects the speed of radical innovation (Figure 1a). This choice of mode of learning during the radical phase also affects the ability to use different modes of learning during the incremental phase (Figure 1b). Furthermore, the sequential path of mode of learning during the radical and incremental phases affects the speed of incremental innovations (Figure 1c).

Figure 1: Conceptual Framework



We now discuss the key components of our conceptual framework: the innovation process and learning.

Innovation as a process

We view innovation in IT-based services as a process that unfolds over time. The innovation process consists of a radical phase followed by an incremental phase. Both the phases lead to commercialization of new IT-based services. The **radical phase** is characterised by the commercialization of a radical innovation and is accompanied by technological as well as market uncertainty within an industry (Garcia and Calantone, 2002). The introduction of online banking in the mid to late 90's is a recent example of an IT-based service that is a radical innovation for the traditional retail banking sector (see Chandy et al., 2003).

A radical innovation in IT-based services creates technological uncertainty because it involves introducing a new electronic system that differs substantially from existing technology in the industry (based on Chandy and Tellis, 1998). From a knowledge-based view, a radical innovation in IT-based services is based on new codified and un-codified knowledge that differs substantially from existing codified and un-codified knowledge in the industry. For example, online banking is based on standard Internet protocols, while traditional banking is based on electronic data interchange (Banks, 2001). Additionally, technological uncertainty during the radical phase arises because there is no consensus among stakeholders within the industry about a commonly accepted architecture with standard components and linkages among components for the radical innovation (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Afuah, 1998). In the case of online banking, two key components are online banking platforms and servers (Starita, 1999). During the radical phase, both these components made use of different meta-languages such as Extensive Mark-up Language (XML), and Open Financial Exchange

(OFX) (Banks, 2001). This lack of consensus during the radical phase results in intense competition among firms to get their design of the radical innovation adopted by a majority of stakeholders within the industry as the standard or the dominant design (Anderson and Tushman, 1990; Sahal, 1981).

Further, a radical innovation causes market uncertainty because a new market infrastructure with new competitors, suppliers and customers begins to emerge (Garcia and Calantone, 2002). For the retail banking sector, online banking led to the possible emergence of new computer-savvy customers, suppliers of technology and technology-savvy competitors. Thus, technological and market uncertainty characterise the radical phase.

The **incremental phase** begins with the emergence of a dominant design (Tushman and Anderson, 1986; Sahal, 1981; Wade, 1995) and is followed by the commercialization of many incremental innovations of the new IT-based service over time. From a knowledge-based view, incremental innovations in IT-based services are based on new codified and un-codified knowledge that builds on existing knowledge of the radical innovation in IT-based services. In the case of online banking, the incremental phase began with the adoption of the Open Financial Exchange (OFX) standard as the dominant design. Emergence of a dominant design implies that the underlying radical technology is well understood by majority of stakeholders in the industry and that the new market infrastructure has developed well. This reduces technological and market uncertainty (Abernathy and Utterback, 1978).

Further, the incremental phase involves the introduction of many incremental innovations in an industry through two steps. First, components of the radical innovation are incrementally developed in terms of performance, quality and price (Dosi, 1982;

Malerba, 1992). Second, these incremental components are then integrated into the existing architecture of the radical innovation to develop incremental innovations (Henderson and Clark, 1990). For example, the incremental phase for online banking involved development of incremental online banking innovations like e-lending, e-brokerage, e-insurance, e-cash management, check image and wireless banking (Furst et al., 2002, 2000). Development of many incremental innovations forces firms to compete on the basis of the number of incremental innovations that they develop.

Now, we discuss the nature of learning in terms of modes of learning and their relation to knowledge.

Learning

The key output of learning is **knowledge.** In this study, we focus on the 'codifiability' dimension of knowledge (Zander and Kogut, 1995). Codifiability is the degree to which knowledge can be represented by symbols. Based on this dimension, we differentiate between two types of knowledge: un-codified and codified knowledge. **Un-codified knowledge** is knowledge that has not been articulated and is not in a communicable form. This knowledge consists of tacit and latent knowledge. Tacit knowledge is difficult to articulate and only exists in the form of experiences (Polanyi, 1958; Nonaka, 1994; Nonaka and Takeuchi, 1995). On the other hand, latent knowledge can be articulated and communicated but remains unarticulated because firms do not have any incentive to articulate it (Agrawal, 2006). For example, software programming skills like writing source code represents tacit knowledge, while the knowledge of possible errors in writing source code for a particular software program represents latent knowledge. Further, **codified knowledge**[5] is knowledge that has been articulated and is in a communicable form, like formal language, symbols and objects. An Enterprise Resource

[5] In the literature, codified knowledge is also termed as explicit knowledge (e.g. Nonaka and Takeuchi, 1995).

Planning (ERP) system[6] for a bank or any other firm is an example of such codified knowledge (Nonaka and Takeuchi, 1995; Choo, 1998). Thus, both codified and un-codified knowledge are key outputs of learning.

Learning is the process of developing knowledge through acquisition, combination and conversion of codified and un-codified knowledge[7] (based on Nonaka, 1994). Learning occurs through two major modes: internal knowledge creation and external knowledge transfer. We define learning through **internal knowledge creation** as a process of learning-by-doing within the firm that involves acquisition, combination and conversion of codified and un-codified knowledge. An example of internal knowledge creation is the development of software for an ERP system. Because internal knowledge creation is a process of learning-by-doing, by definition, it is a slow and uncertain process. Furthermore, because internal knowledge creation leads to un-codified and codified knowledge, it enables the firm to comprehend external similar or related codified knowledge across different fields (based on 'absorptive capacity' concept (Cohen and Levinthal, 1990)). For example, a software developer of an ERP system can comprehend the language and source code of off-the-shelf Customer Relationship Management (CRM) software which is often an adjunct to an ERP system. Further, firms that learn through internal knowledge creation develop the ability to combine internal and external codified knowledge. This is seen in the case of a software developer of an ERP system who understands the changes in source code necessary for integrating a CRM software package with an ERP system.

---

[6] An ERP system is an electronic system composed mainly of software, servers and operating system, which is used for structuring information flow within any firm around the firm's processes.
[7] Literature uses other conceptual terms like assimilation, transformation and exploitation to indicate combination and conversion (see Zahra and George, 2002).

We now discuss the learning mode of external knowledge transfer. We define learning through **external knowledge transfer** as a process of acquisition and combination within the firm of codified knowledge developed outside the firm. An example of external knowledge transfer is the licensing of an ERP system by a firm. Because external knowledge transfer uses knowledge developed by other firms, it is a fast and certain process. On the other hand, because external knowledge transfer does not lead to the development of un-codified knowledge within the firm, it does not enable the firm to comprehend external similar or related codified knowledge across different fields (based on 'absorptive capacity' concept (Cohen and Levinthal, 1990)). For example, a firm that licenses an ERP system cannot comprehend the language and source code of off-the-shelf CRM software. Further, firms that learn through external knowledge transfer do not develop the ability to combine internal and external codified knowledge. This is seen in the case of a firm that licenses an ERP system because it cannot understand the changes in source code necessary to integrate CRM software. Hence, learning through external knowledge transfer and internal knowledge creation not only differ in terms of processes but also in terms of the resulting firm capabilities.

We now extrapolate the links among the key components of our conceptual framework.

Modes of learning and innovation process

Incumbent firms can choose to learn through internal knowledge creation or external knowledge transfer in each phase of the innovation process. In our conceptual framework we propose that choice of mode of learning during the radical phase has an impact on a) innovation outcomes in the radical phase, b) the mode of learning in the incremental phase, and c) innovation outcomes in the incremental phase.

For instance, consider a firm that commits to **external knowledge transfer during the radical phase**. Assume that this firm licenses an ERP system. Such a firm will be faster at radical innovation such as an ERP system since it acquires codified knowledge from another firm. On the other hand, this firm will be constrained in its ability to use external knowledge transfer during the incremental phase since it cannot comprehend and evaluate external similar or related codified knowledge during the radical phase. Thus, a firm that licenses an ERP system will not be able to choose appropriate CRM software with compatible language and source code. Also, external knowledge transfer during the radical phase leads to fewer incremental innovations because of lack of ability to integrate external codified knowledge at the component level with the architecture of the radical innovation. Therefore, the firm that licenses an ERP system will find it very difficult to integrate it with a licensed CRM software package so as to incrementally develop the ERP system to manage customer relationships.

Now, consider a firm that commits to **internal knowledge creation during the radical phase**. Assume that the firm internally develops an ERP system. Such a firm will be slower at radical innovation such as an ERP system than a firm that uses external knowledge transfer since it is focused on developing un-codified and codified knowledge within the firm. This firm, however, will be able to use external knowledge transfer during the incremental phase since it can comprehend external similar or related codified knowledge. Thus, a firm that develops an ERP system will be able to choose appropriate CRM software with compatible language and source code. In addition, internal knowledge creation leads to a greater number of incremental innovations within a period of time because of its ability to integrate codified knowledge at the component level within the architecture of the radical innovation. Hence, the firm that develops an ERP system would be able to integrate the ERP system with a CRM software package so as to incrementally develop the ERP system to manage customer relationships.

We now draw on this framework to formulate hypotheses about the effect of modes of learning during the radical phase on choice of mode of learning during the incremental phase as well as on innovation outcomes in both phases.

Hypotheses

Modes of learning during the radical phase and speed of radical innovation

Past literature focuses either on the effect of internal knowledge creation or on the effect of external knowledge transfer on speed of innovations in general. Studies of internal knowledge creation consider this mode of learning to be important for innovations (see Madhavan and Grover, 1998; Leonard and Sensiper, 1998). A recent empirical study has shown that internal knowledge creation has a positive effect on speed of innovations in general (Smith et al., 2005). Conceptually, these studies emphasize the importance of internal un-codified knowledge.

Further, the studies of external knowledge transfer consider transfer and utilization of knowledge from outside the firm to be crucial for innovations (see Cohen and Levinthal, 1990; Wuyts et al., 2004). Recent empirical studies have shown that external *un-codified* knowledge transfer has a positive effect on speed of innovations in general (e.g., Cavusgil et al., 2003; Agrawal, 2006). Conceptually, studies of external knowledge transfer emphasize the importance of external *un-codified* knowledge.

Thus, far past literature has failed to compare the positive effects of internal knowledge creation to the positive effects of external knowledge transfer on speed of innovations. Nor has the literature empirically examined the effect of either mode of learning on speed of *radical* innovation. Further, it neglects the role of codified knowledge in developing innovations and does not focus on innovation in IT-based services.

In this study, we explicitly compare the effect of internal knowledge creation and external knowledge transfer[8] on speed of radical innovation in IT-based services. We use the knowledge-based view of the firm to argue that the development and use of capabilities (Grant, 1998) and routines (Nelson and Winter, 1982) underlying internal knowledge creation is a slow and difficult process with unpredictable innovation outcomes. Thus, on the one hand, we expect the process of internal knowledge creation during the radical phase to hinder speed of radical innovation. On the other hand, we argue that the development and use of capabilities (Grant, 1998) and routines (Nelson and Winter, 1982) underlying external knowledge transfer is a fast and easy process with predictable innovation outcomes. Thus, we expect the process of external knowledge transfer during the radical phase to facilitate speed of radical innovation.

Internal knowledge creation, by definition is a process of learning-by-doing within the firm that develops knowledge through acquisition, combination and conversion of codified and un-codified knowledge. Building on this definition, we argue that internal knowledge creation during the radical phase is a process that acquires, combines and converts codified knowledge regarding the radical technology to develop un-codified knowledge and codified knowledge in the form of radical innovation in IT-based services (based on Nonaka, 1994). An example of this is the case of incumbent banks that use codified knowledge regarding internet-related technologies to develop online banking websites. The process of internal knowledge creation during the radical phase can be viewed as occurring in stages. Each stage requires the development of routines and capabilities that underlie the interchange between codified and un-codified knowledge (based on Nonaka, 1994). The nature of these routines in terms of being fast or slow to execute and the nature of the capabilities in each stage in terms of being difficult or easy to

[8] In this study, we use the term, 'external knowledge transfer' to indicate transfer of codified knowledge.

develop, ultimately determines the amount of time needed for the complete process and hence, the speed of radical innovation.

In the first stage, incumbent firms acquire codified knowledge regarding the radical technology through training and education of personnel (Smith et al., 2005). This is imperative at the beginning of the radical phase because incumbent firms lack internal knowledge about the radical technology (Chandy and Tellis, 1998). For example, banking personnel learn about internet protocols and meta-languages like XML, OFX, HTML (Hyper Text Mark-up Language) and others. The routines underlying training and education are inherently time consuming.

In the second stage, incumbent firms combine this codified knowledge regarding the radical technology with existing codified knowledge in the firm (Nonaka, 1994). This combination requires the development of creative problem framing and vision-enacting capabilities in teams (Prencipe, 2001). Creative problem framing articulates a problem that might not be obvious and vision-enacting provides a visionary solution that does not already exist in the industry. An example of creative problem framing in the retail banking industry is the identification of the technical limitations in existing technology that precluded development of efficient long distance transactional banking services for retail customers. Similarly, a visionary solution would be to propose the development of an online banking platform that supports transactional processes and is integrated with the front-end user interface and the existing back-end core banking legacy processors (Starita, 1999). Hence, this stage requires capabilities like creative problem framing and vision-enacting in order to combine codified knowledge regarding the radical technology with existing codified knowledge in the firm. These capabilities are difficult and time consuming for firms to develop (Leonard and Sensiper, 1998).

In the third stage, incumbent firms convert codified knowledge regarding possible applications of the radical technology into un-codified knowledge i.e. tacit and latent skills in developing the component(s). These skills are then converted into codified knowledge in the form of components that are integrated with each other and with existing customer information, firm processes and IT infrastructure to develop the radical innovation in IT-based services (Momma, 2000). This conversion process requires trial and error (Eisenhardt and Tabrizi, 1995) and learning-by-doing routines using new problem-solving approaches (Henderson and Clark, 1990). It also requires close social interaction within teams (Leonard and Sensiper, 1998). Trial and error routines are experimental in nature. An example of trial and error would be efforts at writing a software program for an online banking platform. Further, learning-by-doing in the online banking context would involve integrating the online banking platform to servers, back-end core banking legacy processors and front-end user interface to develop the online transactional banking website (Starita, 1999). Hence, this stage requires the use of routines like experimentation and learning-by-doing. These routines have outcomes that are intrinsically uncertain (Aghion and Howitt, 1992; Grossman and Helpman, 1991), and often negative (March, 1991).

The above arguments show that the process of internal knowledge creation during the radical phase is slow.

External knowledge transfer during the radical phase is a process that acquires and combines externally developed codified knowledge regarding the radical innovation in IT-based services within the firm. Again, the process of external knowledge transfer during the radical phase can be viewed as occurring in stages. Each stage requires the development of routines and capabilities that underlie the acquisition and combination of external codified knowledge regarding the radical innovation. Unlike the process of internal knowledge creation, these routines do not underlie interchange between codified and un-codified knowledge.

In the first stage, incumbent firms acquire codified knowledge about the different architectures of the radical innovation that are available for adoption through contractual agreements like licensing. This knowledge is used to select the architecture of the radical innovation and corresponding partner firm for licensing the radical innovation. This is a fast process because it requires partner identification capabilities that are mostly based on selecting the firm which has a popularly accepted design of the radical innovation within the industry (Tegarden et al., 1999). One example is the process of choosing from the online banking solutions offered for licensing by the large number of online banking technology vendors (see Microbanker, 2002).

In the second stage, incumbent firms acquire and combine codified knowledge in the form of radical innovation from outside the firm with existing codified knowledge in the firm (Nonaka, 1994). This is followed by use of codified knowledge from the accompanying operating manuals. The acquisition and integration of the radical innovation from the selected partner is dictated by the rules and legal provisions of a contractual licensing agreement. The routines underlying this acquisition and integration are quickly executed since they require replication of the rules in the contractual agreement (Prencipe and Tell, 2001). Further, the routines underlying the use of the accompanying operating manuals are easy to execute because they require repetitive action (Prencipe and Tell, 2001). Hence, the acquisition and integration of the radical innovation is fast, easy and has outcomes that are usually positive.

Based on the arguments presented in this section, we hypothesize that:

H1: Incumbent firms that learn through internal knowledge creation during the radical phase are likely to be slower at radical innovation in IT-based services compared to incumbent firms that learn through external knowledge transfer during the radical phase.

Modes of learning during the radical phase and modes of learning during the incremental phase

Past literature studies learning at a point in time as well as over time. Some studies focus on combining different modes of learning at a point in time within the innovation context (Arora and Gambardella, 1994; Cassiman and Veugelers, 2001; 2002). Others focus on the effect of past learning on present learning (i.e. on the path-dependent nature of learning over time) (Arthur, 1990; Cohen and Levinthal, 1994; Eisenhardt and Martin, 2000; Patel and Pavitt, 1997). Empirical studies show that firms that use a particular mode of learning in the past continue to use the same mode of learning in the present (Pisano, 1990; Hagedoorn and Duysters, 2002). However, the literature on learning over time does not differentiate between learning during the radical and incremental phases of the innovation process. This shortcoming is critical because the nature of innovation during the radical and incremental phases requires different modes of learning. A failure to take this aspect into account limits a complete conceptual and empirical understanding of the path dependency between modes of learning. Indeed, current knowledge on path dependency in the innovation context would assume that firms which use one mode of learning (say, internal knowledge creation) during the radical phase will continue to use the same mode of learning during the incremental phase. We argue that this assumption is unlikely to hold.

We study the path-dependent effect of choice of mode of learning during the radical phase on choice of mode of learning during the incremental phase. We use the knowledge-based view of the firm to argue that incumbent firms which choose either mode of learning during the radical phase *prefer* external knowledge transfer to internal knowledge creation during the incremental phase. However, incumbent firms that choose internal knowledge creation instead of external knowledge transfer during the radical phase develop the ability to more effectively transfer external codified knowledge and hence, are *more likely to use* external knowledge transfer during the incremental phase. We elaborate on this argument below.

Incumbent firms that choose either mode of learning during the radical phase have two choices during the incremental phase: adopt incremental developments of components from outside the firm through external knowledge transfer, or develop the components incrementally within the firm through internal knowledge creation. The incremental development of components within the firm requires the combination of multiple ideas. It also requires problem solving skills across many technological fields (Patel and Pavitt, 1997; Henderson and Clark, 1990). The development of such skills is a very costly and time consuming investment for any single firm (Pisano et al., 1988; Powell et al., 1996). Thus, all incumbent firms that choose internal knowledge creation during the incremental phase are limited in the range of incremental components that they can develop internally.

Alternately, the adoption of externally developed incremental components from outside provides the firm multiple options in terms of a broad range of incremental components that are available on the market. These externally available incremental components embody multiple ideas and problem solving skills from many different firms. Thus, all incumbent firms that choose external knowledge transfer during the incremental phase have a vast choice in terms of range of incremental components that they can obtain from the outside. This makes external knowledge transfer the preferable mode of learning during the incremental phase. Hence, incumbent firms that choose either mode of learning during the radical phase *prefer* external knowledge transfer to internal knowledge creation during the incremental phase.

However, incumbent firms that choose different modes of learning during the radical phase differ in their ability to *effectively* transfer external codified knowledge during the incremental phase. Incumbent firms that choose internal knowledge creation during the radical phase develop un-codified and codified knowledge that provides them two fold capabilities to transfer external codified knowledge more effectively during the incremental phase.

First, incumbent firms with *internal un-codified knowledge* regarding existing components and architecture of the radical innovation are able to convert external related codified knowledge in the form of incremental components into un-codified knowledge within the firm (based on Nonaka, 1994; Cohen and Levinthal, 1990; Zahra and George, 2002). This facilitates monitoring and evaluation of externally developed incremental components (Prencipe, 1997, 2001; Granstrand, Patel and Pavitt, 1997). For example, incumbent firms that internally develop an ERP system create internal un-codified knowledge in the form of programming skills. These internal programming skills allow reverse engineering[9] of an externally developed vendor CRM package so as to understand its database structure and conceptual model (Blaha, 1998). This understanding provides an evaluation of the quality of the CRM package which represents development of new un-codified knowledge within the firm (Blaha, 1998).

Second, incumbent firms with *internal codified knowledge* regarding existing components and architecture of the radical innovation are able to combine this codified knowledge with external related codified knowledge regarding incremental components (based on Nonaka, 1994; Cohen and Levinthal, 1990; Zahra and George, 2002). This facilitates evaluation and identification of externally developed incremental components that are compatible with the architecture (Prencipe, 1997, 2001; Granstrand, Patel and

[9] Reverse engineering of a database is a program analysis technique that used sophisticated tools to deduce the logical structure of the database (Muller et al., 2000).

Pavitt, 1997). Consider a dialogue between an incumbent firm and a vendor in order to evaluate compatibility of the vendor's off-the-shelf CRM package with the other components and overall architecture of the incumbent firm's ERP system. Such a dialogue is facilitated when the incumbent firm has internal codified knowledge about the architecture of the ERP system (Blaha, 1998).

The above arguments show that incumbent firms that choose internal knowledge creation during the radical phase are able to effectively transfer external related codified knowledge during the incremental phase through the use of internal codified and un-codified knowledge.

On the other hand, incumbent firms that choose external knowledge transfer during the radical phase adopt some codified knowledge in the form of rules contained in manuals of the radical innovation but do not adopt un-codified knowledge regarding the radical innovation. This lack of internal un-codified knowledge and availability of very specific internal codified knowledge hinders effective transfer of external codified knowledge during the incremental phase in two ways. First, incumbent firms *without internal un-codified knowledge* regarding existing components and architecture of the radical innovation are unable to convert external codified knowledge in the form of incremental components into un-codified knowledge within the firm (based on Nonaka, 1994; Cohen and Levinthal, 1990; Zahra and George, 2002). Second, incumbent firms *with specific internal codified knowledge* from manuals of the radical innovation are unable to combine it with external codified knowledge regarding incremental components since the two knowledge bases are dissimilar (based on Nonaka,1994; Cohen and Levinthal, 1990; Zahra and George, 2002).

Both factors hinder effective monitoring, evaluation and identification of appropriate incremental components during the incremental phase (Prencipe, 1997, 2001; Granstrand, Patel and Pavitt, 1997). For example, incumbent firms that license an ERP system cannot effectively evaluate quality of off-the-shelf CRM packages since they lack the internal programming skills to reverse engineer them. These incumbent firms also fail to effectively evaluate compatibility of the CRM package with the ERP system because they lack codified knowledge of the existing components and architecture of the ERP system[10]. Hence, such incumbent firms are unable to acquire the broad range of incremental components available on the market during the incremental phase.

The above arguments show that incumbent firms that choose external knowledge transfer during the radical phase are unable to effectively transfer external codified knowledge in the form of incremental components during the incremental phase. Nevertheless, these incumbent firms have two other options. First, they can develop a limited range of incremental components through internal knowledge creation during the incremental phase. For example, incumbent firms that license an ERP system could develop CRM software internally by employing software developers or by using a software consultant. Second, these incumbent firms can acquire the limited range of incremental components developed externally by the same partner firm from whom they licensed the radical innovation during the radical phase. In this way, they avoid the need to monitor, evaluate and identify external incremental components for quality and compatibility.

To sum up this discussion, in this section, we argue that incumbent firms that choose different modes of learning during the radical phase are similar in their preference for external knowledge transfer over internal knowledge creation during the incremental

[10] Although evaluation of quality and compatibility is not possible, evaluation of the CRM package in terms of cost, vendor stability, functionality and attractiveness of the user interface might be possible (Blaha, 1998).

phase. However, these incumbent firms differ in their ability to effectively transfer external codified knowledge during the incremental phase. Specifically, incumbent firms that choose to learn through internal knowledge creation during the radical phase are able to more effectively transfer external codified knowledge during the incremental phase as compared to incumbent firms that choose to learn through external knowledge transfer during the radical phase.

Hence, we hypothesize that:

> H2: Incumbent firms that learn through internal knowledge creation during the radical phase are more likely to use external knowledge transfer during the incremental phase as compared to incumbent firms that learn through external knowledge transfer during the radical phase.

Modes of learning during the innovation process and speed of incremental innovations

Past literature focuses on the effect of combining modes of learning at a point in time on speed of innovations in general. Such studies are limited (e.g. Rosenkopf and Nerkar, 2001; Tsai, 2001; Prabhu et al., 2005). These studies fail to conceptually and empirically focus on the effect of path-dependent modes of learning during the innovation process on the speed of innovations. These studies also do not focus on innovation in IT-based services.

In this study, we compare the effect of path dependency of modes of learning during the radical and incremental phases on the speed of incremental innovations. Here, we use the term 'speed of incremental innovations' to indicate the number of incremental innovations developed during a fixed time period. We use the knowledge-based view of the firm to argue that on the one hand, incumbent firms that learn through the path of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase develop capabilities that facilitate speed of incremental innovations. On the other hand, incumbent firms that learn through either of the following two paths are slower to develop incremental innovations: external knowledge transfer during the radical phase followed by external knowledge transfer during the incremental phase, or external knowledge transfer during the radical phase followed by internal knowledge creation during the incremental phase.

Incumbent firms that learn through the path of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase develop capabilities through:

i) Codified and un-codified knowledge regarding the radical innovation

ii) Codified and un-codified knowledge regarding incremental components

iii) Social relationships within teams

Integrating codified knowledge in the form of incremental components with codified knowledge in the form of the radical innovation is the key to developing incremental innovations (Van den bosch et al., 1999). This is particularly the case for IT-based services which are composed of knowledge. Un-codified knowledge regarding the radical innovation along with social relationships within teams and un-codified knowledge regarding incremental components facilitates this integration process.

Un-codified knowledge regarding the radical innovation is imperative for integration. Both latent and tacit components of un-codified knowledge are important. For example, latent knowledge of the ERP system in terms of architecture and design tradeoffs, engineering constraints, and the application domain that only exists at the sub-conscious level among the software engineers is important for integrating the vendor CRM package with the internal ERP system (Muller et al., 2000). Further, tacit knowledge about the changes required in source code of the ERP system is crucial to allow integration with the vendor CRM package (Muller et al., 2000).

Social relationships have an indirect effect on the integration process through their impact on un-codified knowledge regarding externally developed incremental components. This un-codified knowledge is obtained through the conversion of externally developed codified knowledge during the incremental phase and tends to be 'sticky' (i.e. it is difficult to transfer within the firm) (Szulanski, 1996). Hence, it remains localized in some parts of the firm without being beneficial to other parts. Social relationships help in transferring 'sticky' un-codified knowledge regarding external components to different personnel and teams within the firm (see Szulanski, 1996; Zahra and George, 2002). This transfer within the firm of un-codified knowledge regarding external components is essential to ensure that it facilitates integration (von Hippel, 1994; Spender, 1996).

Un-codified knowledge regarding externally developed incremental components is also imperative for the integration process (Prencipe, 2000; Granstrand et al., 1997). It facilitates assessing, testing and integration of these components (Prencipe, 2000; Granstrand et al., 1997). For example, the understanding of database structure, conceptual model and source code of vendor CRM package through reverse engineering is important for effective integration with internally developed ERP system (Blaha, 1998).

In summary, incumbent firms that learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase are able to efficiently integrate incremental components into the architecture of the radical innovation, and hence, develop many incremental innovations in IT-based services over a fixed time period.

Between the other two paths, incumbent firms that learn through the path of external knowledge transfer during the radical phase followed by external knowledge transfer during the incremental phase possess:

i) Codified knowledge that includes the radical innovation and related manuals

ii) Codified knowledge that includes incremental components and related manuals

The previous arguments in this section indicate that incumbent firms that lack un-codified knowledge regarding radical innovation along with social relationships and un-codified knowledge regarding incremental components are unable to efficiently integrate incremental components with the radical innovation architecture. Hence, such incumbent firms will develop fewer incremental innovations as compared to incumbent firms that learn through the path of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase.

The other alternative path is for incumbent firms to learn through external knowledge transfer during the radical phase followed by internal knowledge creation during the incremental phase. These incumbent firms possess:

i) Codified knowledge that includes the radical innovation and related manuals

ii) Codified knowledge that includes incremental components and related manuals

iii) Un-codified knowledge regarding internally developed incremental components

iv) Social relationships among teams

The previous arguments show that the incumbent firms which lack un-codified knowledge regarding the radical innovation do not have the skills required to change its technical aspects for integrating incremental components to its architecture. Nonetheless, these incumbent firms are able to use un-codified knowledge regarding incremental components and social relationships among teams to obtain the necessary level of integration needed for successful incremental innovations. Hence, such incumbent firms will be more efficient at integration as compared to incumbent firms that learn through the path of external knowledge transfer during the entire innovation process. These incumbent firms will develop relatively more incremental innovations. On the other hand, such incumbent firms will be less efficient at integration as compared to incumbent firms that learn through the path of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase. The former incumbent firms will develop relatively fewer incremental innovations than the latter.

To sum up this discussion, in this section, we argue that incumbent firms which learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase are able to more efficiently integrate incremental components into the architecture of the radical innovation compared to incumbent firms which learn through other paths.

Hence, we hypothesize that:

> H3: Incumbent firms that learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase are likely to develop more incremental innovations in IT-based services compared to other incumbent firms.

In the following sections we describe the empirical context of our study, select a appropriate sample and test our hypotheses using appropriate models.

Chapter 3: Methodology

Empirical context

Our conceptual framework provides arguments about the effect of incumbent firms' choice of path-dependent modes of learning during the innovation process on the speed of radical innovation during the radical phase and the speed of incremental innovations during the incremental phase. To test the emerging hypotheses, we need first, an industry context with a single innovation in IT-based service that allows clear identification of the innovation process as composed of a radical phase followed by an incremental phase. This is a key requirement for our study.

Second, we need an industry context where there are sufficient incumbent firms with the resources to explore several modes of learning. This is an important requirement because financial resources influence the ability to invest in different modes of learning (see Keeton, 2001; Furst et al., 2000; Carlson et al., 2000). Since we study incumbent firms' choice of mode of learning as being path-dependent on past learning, it is necessary to exclude firms that are constrained in their choice due to lack of financial resources.

Third, we need an industry context where there are sufficient incumbent firms that develop the radical innovation during the radical phase and not during the incremental phase. This requirement ensures that in line with our research question and conceptual framework we study incumbent firms that are active throughout the innovation process. Thus, we study incumbent firms that develop the radical innovation during the radical phase and exclude firms that develop the radical innovation only during the incremental phase.

Online retail banking in the U.S. from 1st May 1995 to 31st December 2003 provides a context that meets these criteria. First, online retail banking is a good example of the innovation process in IT-based service. It has been identified as a powerful radical innovation for the retail banking industry (see Chandy et al., 2003) and has evolved incrementally over time (see Microbanker, 2001). The radical phase for the online retail banking industry in the U.S. is easy to identify from secondary sources. Details of the method used for calculating the time frame for the radical phase are presented in the section on Sampling. We find that the radical phase starts in May 1995 and ends in December 1999 with the emergence of a dominant design for the online transactional banking innovation. This provides us an excellent time frame from 1st January 2000 up to 31st December 2003 to examine subsequent incremental development of online transactional banking over time.

Second, a sufficient number of incumbent banks in the U.S. online retail banking industry have the resources to explore different modes of learning. The large number of incumbent retail banks in the U.S. at the end of 2003[11] provides a set of large, medium and small banks (in terms of assets in 1994) from which a sample can be selected.

Third, the U.S. online banking context provides a sufficient number of incumbent banks that started transactional online banking during the radical phase. This is a result of the fast rate at which basic online transactional banking websites grew in the U.S. from 1996 to 2000 (Hall et al., 2002).

Thus, the U.S. online retail banking industry meets our criteria for a suitable empirical context. Additionally, substantial accurate data over time is available for

[11] 9195 FDIC insured commercial and savings institutions at the end of 2003.

individual banks. Such data is collected and made available to the public by regulatory agencies such as the Federal Reserve Board, the Federal Deposits Insurance Corporation (FDIC), and the Office of the Comptroller of Currency (OCC).

Sampling Procedure

It follows that to test the hypotheses we need to (1) calculate the radical phase for the U.S. online banking industry, and (2) select a sample of incumbent firms that meets the requirements of the hypotheses. We use two samples in this study. We use the first sample to calculate the radical phase and the second sample to test the hypotheses. We now explain this sampling procedure in detail:

Obtaining the population

We first obtain the population for this study. Since, this study focuses on incumbent firms that innovate over time we require the population for this study to consist of all incumbent retail banks in the U.S. that had transactional online banking websites as of 31st December 2003. We obtain a complete list of 4341 FDIC insured retail banks with online transactional banking websites as of 31^{st} December 2003. This list was created by the statistics department of FDIC by screening information from self reported mandatory annual call reports of all 9195 FDIC insured retail banks at the end of 2003. Further, we check all 4341 banks to identify non-incumbents. We use information from a survey of online banks (Online Banking Report, 1999) that classifies each bank as incumbent or non-incumbent. We detect 11 non-incumbent banks and filter them. Thus, we obtain the population of 4330 FDIC insured retail incumbent banks with online transactional banking websites as of 31st December 2003.

Obtaining the first sample

The first sample is used to collect data and calculate the radical phase. We require the first sample to consist of a manageable number of banks for which data regarding the month and year of introduction of online transactional banking can be obtained. For this, we randomly select 428 banks (10%) from the population. We collect data from two sources: the Internet Archives and the Thomson online directory. First, we visually inspect all 428 banks' archived web sites for the month and the year of introduction of online transactional banking. Access to the archived web sites is available through the Wayback Machine of the Internet Archives (see www.archive.org). Second, we obtain data on the month and the year of introduction of online transactional banking from the Thomson online directory[12]. We use this data to complement and to cross-check the data from the Wayback Machine. Although this procedure is manually intensive and time consuming, it ensures the reliability and validity of our data.

To obtain the first sample, we filter 58 banks for whom data on year of introduction of online transactional banking was not obtained from the Thomson online directory or the Internet Archives. Thus, we obtain the first sample of 359 incumbent retail banks with recorded month and year of online transactional banking. The representativeness of this sample is checked with a t-test. The mean of assets for this sample is not significantly different from that of the population.

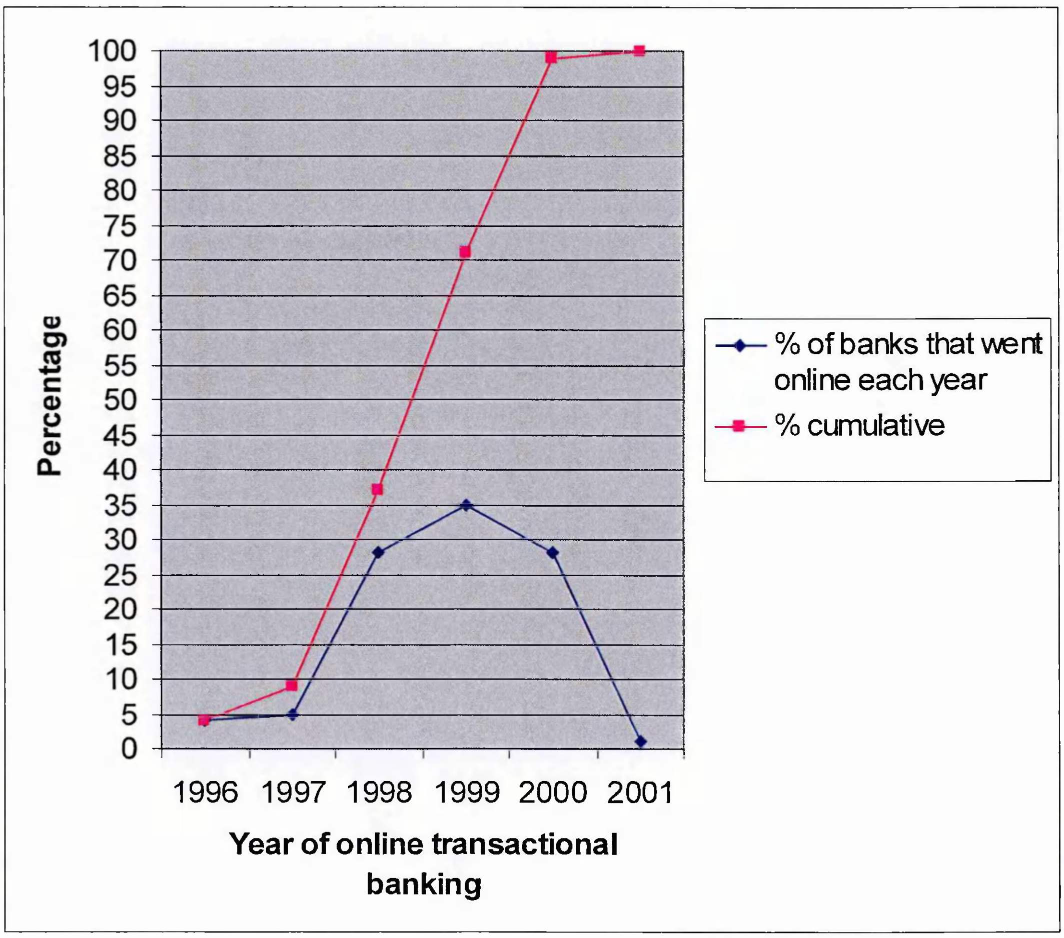
Calculating the radical phase

We now use the data collected for the first sample to plot a graph that shows the percentage and cumulative percentage of banks that introduced online transactional banking each year from 1995 (see Figure 2). We use the data collected and the information from this graph to calculate the time frame for the radical phase. Data from Internet

[12] Details regarding these data sources and the data collection procedure are provided in the section on "Measures and Sources" under the heading 'Speed of radical innovation".

Archives, Thomson online directory and other secondary sources (e.g. Banks, 2001) indicates that the first incumbent bank to introduce online transactional banking in the U.S. was Wells Fargo in May 1995. Further, the graph shows that the cumulative percentage of incumbent banks that introduced online transactional banking peaked in 2000. Following the approach of Anderson and Tushman (1990), we deduce that the radical phase ends just before the peak in 2000. Hence, the time frame pertaining to the radical phase for the U.S. online retail banking industry is from *1st May 1995 to 31st December 1999.*

Figure 2: Introduction of Transactional Online Banking



Obtaining the second sample

The second sample is used to test the hypotheses. So, we require this sample to consist of retail incumbent banks which had sufficient financial resources at the beginning of the radical phase and introduced online transactional banking services during the radical phase. We use the data on year of introduction of online transactional banking for each bank in the first sample to filter out 101 incumbent banks that did not start innovating during the radical phase. Further, we collect data on assets at the end of 1994 for each bank in the first sample from the FDIC website. We filter 169 incumbent banks with assets less than US$1b because statistics indicates that a small proportion of these banks invest in internal knowledge creation through in-house technology development as compared to incumbent banks with assets greater than US$1b (see Keeton, 2001; Furst et al., 2000; Carlson et al., 2000). This implies that incumbent banks with assets greater than US$1b are not constrained in their choice of mode of learning by lack of financial resources. The hypotheses require that the sample consist of incumbent firms with the resources to explore several modes of learning. So, we include only large banks with assets greater than US$1b in our sample. Thus, we obtain the second sample of 89 large incumbent retail banks that had introduced online transactional banking during the radical phase. This sample was used to collect data on independent, dependent and control variables, and subsequently, to test the hypotheses.

Measures and Sources

The sample for hypotheses testing is a longitudinal data set of 89 incumbent banks over a period of nine years (from 1995 to 2003). For the key variables, we used multiple data sources and objective measures that ensure reliability and validity of our data. Our approach is better than a conventional survey approach since information on innovations like speed of radical innovation or speed of incremental innovations are prone to self-report and memory biases (see Golder and Tellis, 1993). We list the measures and data sources for our constructs and variables in Table 1. Note that the constructs 'innovation during radical phase' and 'innovation during incremental phase' comprise of the variables 'speed of radical innovation' and 'speed of incremental innovations' respectively. Also, the constructs 'learning during radical phase' and 'learning during incremental phase' comprise of the variables 'internal knowledge creation during radical phase' and 'external knowledge transfer during incremental phase' respectively. In the following section, we discuss the measures and data sources for the variables in detail.

Speed of radical innovation

Speed of radical innovation indicates how fast an incumbent bank introduces basic transactional banking services on its website compared to the introduction of the first online transactional banking service. The benchmark for all banks is the date of introduction of the first online transactional banking website in the U.S. i.e. May 1995 (operationalised as 1st May 1995). More precisely, we count the number of months that an incumbent bank takes to introduce basic transactional banking on its website after May 1995. For example, the speed of radical innovation for an incumbent bank which introduced this service in June 1996 would be 13 months.

We collect the information on month and year of introduction of online transactional banking by each bank from the Wayback Machine of the Internet Archive (see www.archive.org) and the Thomson directory of online banking.

The Wayback Machine is the search engine of the Internet Archive which provides access to 40 billion web pages archived from 1996. The Internet Archive aims at building an 'Internet library'. It receives donations from Alexa Internet which sends its crawlers out into the web roughly once every two months and retrieves copies of virtually everything it encounters. This makes the Internet Archive the perfect source for retrieving past information from archived websites of each bank in our sample. It allows visual inspection of the archived websites for detecting the month and year when the website started offering basic transactional functions like balance inquiry, fund transfer, and bill payment.

The thomson directory of online banking is an annual publication from 1997 to 2001. It publishes the month and the year of introduction of basic online transactional banking for selected banks. We use the information collected from the Thomson directory to cross-check the reliability of the information obtained from the Internet Archives. Both the sources support each other except in two cases, in which the Internet Archives are more accurate. In a few other cases, information is available from only one of the sources and so we rely on this source. For example, information is not available from the Internet Archives when robotic technology put in place by the bank did not allow their website to be archived. Also, information is not available from the Thomson directory when the particular bank is not included on its list of selected banks.

Both the sources of online transactional banking dates are more objective and superior to a conventional survey method. This is because survey data on online transactional banking dates is prone to memory bias. Additionally, such data might be considered as sensitive information by banks, many of them might be reluctant to disclose this information in a survey. In a telephone discussion of this study, Dr. Nolle, a Senior Financial Economist at the OCC, he commented that, ".....through the use of the Internet Archives you have access to more precise information than what the banks themselves might have today."

Speed of incremental innovations

Speed of incremental innovations indicates how fast an incumbent bank introduces incremental banking services on its website. More precisely, we count the number of incremental banking services that an incumbent bank introduces on its website till the end of December 2003. We specifically look for the introduction of online banking functions related to the incremental online banking services of e-lending, e-brokerage, e-insurance, e-cash management, check image and wireless banking. We choose these six services because they are cited as key incremental innovations in online banking by Furst et al. (2002, 2000) and Microbanker (2001), a company specializing in online banking. Thus, this count of incremental innovations has values that range from 0 to 6.

We collect information on incremental online banking services introduced by each bank from two sources: bank websites and news archives. We browsed the website of each bank in our sample in December 2003 and looked for the offering of incremental online banking services. We also searched the news archives from 1996 to 2003 on each bank's website and the news archives on each technology vendor's website for announcements of incremental online banking services. We obtain information on the name and website address of 86 online banking technology vendors in the U.S. from the directory of banking technology vendors published by Microbanker in 2003.

The two sources confirm and complement each other. The news archives are used to cross-check the reliability of the information from the websites. Among the two sources, browsing the websites provides more exhaustive information than is available from the news archives. This is because incumbent firms are not required to announce their new incremental banking services through the news. However, the information from news archives for check image and wireless banking services is more exhaustive as websites often do not provide this information.

Further, news archives on technology vendor websites sometimes provide information that is also relevant to the operational measure for the variable 'external knowledge transfer during incremental phase'. For example see the following news item:

> "Gold Systems, Inc., an independent provider of easy-to-use voice and wireless Web solutions for Global 2000 companies, today announced that Provident Bankshares will implement the first Internet banking system that provides both PC-based and wireless access using Gold Systems' wireless application technology."

Source: Mobic (2001)

This news gives information on the introduction of wireless banking, an incremental innovation by Provident Bankshares. It also provides information about licensing agreements. Such a licensing agreement, as the one between Provident Bankshares and Gold Systems for wireless application technology is the operational measure we use for learning through external knowledge transfer during the incremental phase.

In the existing literature, innovative activity of firms has been measured by cumulating innovations over time for each firm in a sample to obtain a cross sectional data set (e.g. Roberts and Amit, 2003; Jones, 2003; Nobeoka and Cusumano, 1997). We use a similar approach.

We now discuss the measures and data sources used for the variable 'learning through external knowledge transfer during incremental phase' followed by the variable 'learning through internal knowledge creation during radical phase'.

External knowledge transfer during the incremental phase

Learning through external knowledge transfer during the incremental phase indicates the choice of mode of learning by an incumbent firm during that phase. Incumbent firms can choose to learn through internal knowledge creation or through external knowledge transfer during the incremental phase. We create a measure of the variable 'external knowledge transfer during incremental phase' that quantitatively indicates the degree of use of external knowledge transfer and the predominant choice between external knowledge transfer and internal knowledge creation.

We empirically measure external knowledge transfer through the incumbent firms' creation of licensing agreements (see Hansen, 1999; Szulanski, 1996; Cavusgil, Calantone and Zhao, 2003). More precisely, we count the number of licensing agreements till 31st December 2003 of each bank in our sample as a measure of external knowledge transfer during the incremental phase. We specifically count only those licensing agreements that acquire technology components for developing incremental online banking services such as e-lending, e-brokerage, e-insurance, e-cash management, e-check, and wireless banking. This count of licensing agreements has values that range from 0 to 12. A higher value of external knowledge transfer for incumbent firms indicates a greater degree of use of external knowledge transfer by these firms compared to firms that have a lower value. It also indicates the predominant choice of external knowledge transfer over internal knowledge creation compared to firms that have a lower value.

We obtain the data on number of licensing agreements of each bank in the sample by combining information from multiple sources: Bank Systems and Technology, SDC Platinum (Securities Data Companies), Factiva, bank news archives and news archives of all online banking technology vendors in the U.S who are included in the Microbanker directory. We are required to combine information from all these sources because none of the sources by itself is exhaustive. For example, SDC Platinum database has been considered as the most comprehensive source of information on licensing agreements, although it is acknowledged as being non-exhaustive (see Anand and Khanna, 2000). We find support for this lack of exhaustiveness, when we compare SDC Platinum with other data sources. Hence, we create a more complete and exhaustive dataset by combining information from SDC Platinum with information from other sources.

Each data source has announcements about strategic alliances in the banking industry. The announcements include purpose statements along with the identities of participating firms and the type of contract (acquisition, joint venture or licensing agreement). Our use of multiple data sources ensures that our final dataset is reliable, valid and exhaustive. We carefully scan the purpose statements of these announcements manually on a case-by-case basis for licensing agreements of each bank in our sample. The details of this scanning procedure are given below.

SDC Platinum is a database of Thomson Financial which obtains information from publicly available sources, including SEC filings, trade publications, news and wire sources. We scan 524 announcements classified under the heading 'Strategic Alliances' by SDC. We carefully read the provided synopses in order to identify licensing agreements created with the purpose of acquiring incremental technology components. SDC Platinum classifies such agreements as 'Licensing Services', 'Financial Services', 'Banking Services' or 'Internet Services'.

Bank Systems and Technology is a specialized monthly banking technology publication. We scan approximately 650 strategic alliances related to bank systems and technology provided under the heading 'Deals & Alliances' or 'Bank Bytes' from February 1997. We read the purpose statement for each alliance along with the identities of the participating firms and the type of contract. Information available from Bank Systems and Technology is the most comprehensive of all the sources that we use.

Factiva is a database which provides full-text coverage of past and current major newspapers, business magazines, network transcripts, wire services, academic and trade journals, etc. We search the database for news items on online banking industry using keywords like Licensing, Information Technology, New products/services, Outsourcing and Market research. We read the full-text news items to identify the relevant licensing agreements for banks in our sample. Some news items coincide with information available in SDC.

Similar to the search process used for measuring the number of incremental innovations, we browse online news archives of all online banking technology vendors in the U.S. from 1996 to 2003. This process allows us to combine information from a large number of public sources to obtain exhaustive information on the number of licensing agreements during incremental phase.

Internal knowledge creation during the radical phase

Learning through internal knowledge creation during radical phase indicates the choice of mode of learning by an incumbent firm during that phase. Incumbent firms can choose to learn through internal knowledge creation or through external knowledge transfer during the radical phase. We create a measure of the variable 'internal knowledge creation during radical phase' that quantitatively indicates the incumbent firm's choice between internal knowledge creation and external knowledge transfer.

We empirically measure internal knowledge creation through the use of in-house technology development (Polyani, 1958). More precisely, we note the use of in-house development for two radical technology components of online retail banking in each bank in our sample as a measure of internal knowledge creation during the radical phase. We label the in-house development of each radical technology component as 1 and the licensing of each radical technology component as 0. Since, we consider the in-house technology development of two radical technology components we obtain values that range from 0 to 2. A value of 2 indicates the in-house technology development of both components. A value of 1 indicates the in-house technology development of one component while a value of 0 indicates the absence of the use of in-house technology development for either component. This value also indicates the licensing of both components.

We now provide details about the two radical technology components for online retail banking innovation. These radical technology components consist of web servers and the online banking platform (Starita, 1999). A web server is required to host the initial non-transactional banking website (Gupta, Rao and Upadhyaya, 2004). An online transactional banking platform is required to add basic transactional functions like account information retrieval and account update. It supports transactional processes and interfaces between the front-end user interface and the back-end core banking legacy processors (Starita, 1999).

We collect information on use of in-house or licensed servers from InterNIC's Whois registry (see www.internic.net). InterNIC provides public information regarding Internet domain name registration and is operated by Internet Corporation for Assigned Names and Numbers (ICANN). InterNIC's Whois search engine provides comprehensive information regarding millions of registered domain names with different extensions from multiple registrars or domain registration services. We obtain information regarding all the banks in our sample by using their web addresses. Information from InterNIC includes the names of servers for the online banking website of the incumbent banks in our sample. The name of the server reveals whether it is in-house or licensed.

We collect data on the use of in-house or licensed online banking technology platform by combining information from online banking report (1999) and a telephone survey. Online banking report (1999) contains information from 1561 U.S. banks regarding their choice of in-house technology development or licensing of online transactional banking platform. This information was obtained from the banks between 1997 and 1999. This time frame ensures that the information pertains to choice made during the radical phase. We conducted a telephone survey of 20 incumbent banks in our sample for whom information was not available from online banking report. We contacted the online banking managers of the banks for this information. Ten banks refused to provide the information because they considered it sensitive.

In the existing literature in-house technology development is usually measured by the actual IT expenditure or R&D expenditure of each firm (e.g. Arora and Gamberdella, 1994). Our selected measure, which identifies the presence of in-house web server and online banking platform is a more precise, objective and unique measure of in-house technology development. The data on IT expenditure or R&D expenditure is broader because it includes spending on all IT infrastructure. This includes expenditure on front-office automation hardware and software that is not related to online banking technology and hence, is not suitable for our purpose.

Controls

Innovation and choice of mode of learning depend on many other variables like size, profitability, regulatory body and unfulfilled needs of target market of the firms. We collect data on appropriate measures of these variables and control for them. All the information is obtained from the Institution Directory of the FDIC (see www.fdic.gov). Details for the measures of the data are provided below.

Size

We measure size as the natural log of employees in 1994. Our sample consists only of banks with assets greater than US$1b. Still, there is sufficient variance on size in our sample to warrant control. Size is used as a control variable for H1 and as an additional exogenous instrumental variable for H2, H3 and additional analysis. Size is used as an exogenous instrumental variable because it is correlated with the endogenous variable (licensing agreements) in H3 and in the additional analysis making it very suitable for use as an instrumental variable. We also use another measure of size (i.e. deposits in 1994) to check robustness of our models. We obtain similar results.

Profitability

We measure profitability as the natural log of return on assets in 1994. Profitability is a measure of availability of resources for investment (Borenstein, 1990, 1991). Firms' resource base has been shown to be important for innovation (Sorescu et al., 2003) and for investment in different modes of learning (see Keeton, 2001; Furst et al., 2000; Carlson et al., 2000). Hence, profitability of a firm can have an important influence on choice of mode of learning and innovation outcomes. Profitability is used as a control variable in H2, H3 and additional analysis.

Charter

Charter is a classification code assigned by FDIC on the basis of the banks charter class, namely, commercial or savings institution, state or national charter agent, federal reserve member or non-member, and based on its primary federal regulator. We measure charter by coding banks in terms of those that have a national charter (coded as 1), or a state charter (coded as 0). Dual charter system (i.e. choice of banks to be regulated by state or federal government) is unique to the U.S. banking system and has fostered steady innovations in banking in the U.S. (ABIA, 2006; Greenspan, 1997). Hence, we control for banks' charter in terms of being state or national for all our hypotheses.

Asset concentration

Asset concentration is an indicator of a bank's primary specialization. Using this criteria FDIC classifies banks into mutually exclusive groups having international, agricultural, credit-card, commercial, mortgage and consumer lending specialization. We dummy code banks that specialize in commercial and industrial loans as 1, and those that specialize in international operations and consumer lending of various types (agricultural, credit-card and mortgage) as 0. Both categories have different target markets with a varying need for online banking innovations.

Rurality

Rurality is an indicator of the degree of rural areas covered by banks' branches. We create a measure of rurality for each bank by using the formula:

$$\frac{\sum CountyRuralCode \times No.ofBranches\_perCounty}{TotalNo.ofBranches}$$

County rural codes measure the degree of rurality for each county in the U.S. We obtain data on county rural codes or rural-urban continuum codes from the Economic Research Service web site (see www.ers.usda.gov). Further, we count the number of branches of each bank in all counties by using data on number of branches per county as well as the date of the branch's creation. We include branches that were created before the end of 1994 in our measure of number of branches. This information on branches per country for each bank is obtained from the FDIC web site. Our measure of rurality is continuous and ranges from 0 to 6.17. It identifies the target market in terms of being more or less rural. This degree of rurality indicates different target markets with a varying need for online banking innovations.

Preparedness

Preparedness indicates the time taken by an incumbent bank in starting investment in online banking technology compared to the first investment in this technology. The beginning of investment in online banking technology is measured by the registration date of a bank's domain name with a registry. The benchmark for all banks is the date of registration of the first domain name in our sample i.e. 2nd February 1991. More precisely, we measure preparedness by counting the number of months that an incumbent bank takes to register a domain name after 2nd February 1991. For example, the preparedness for an incumbent bank which registered its domain name on 1st March 1992 would be 13 months. Banks that take a longer time to start investment in online banking technology will be less prepared as compared to banks that take shorter time to start investment in this radical technology.

We collect the information on registration date of each bank's domain name from Inter NIC's Whois registry (see www.internic.net). We use this data to calculate preparedness. Preparedness is a measure of learning about the radical technology before the radical phase. Effect of past learning on present learning (i.e. path-dependent nature of learning over time) has been well established in the literature (Arthur, 1990; Cohen and Levinthal, 1994; Eisenhardt and Martin, 2000; Patel and Pavitt, 1997). Hence, preparedness can have an important direct influence on choice of mode of learning during the incremental phase and indirect influence on innovation outcomes during the incremental phase. Preparedness is used as a control variable in H2, H3 and additional analysis.

So far we have been discussing the measures and sources of data used in this study. We now discuss the selection of appropriate models to test the hypotheses.

Models

Overall, we hypothesize that learning through internal knowledge creation during the radical phase has a negative direct impact on speed of radical innovation (H1), but a positive indirect impact on speed of incremental innovations (H3). This positive indirect impact combines two effects, suggested by H2 and H3. In H2, we hypothesize the positive effect of internal knowledge creation during the radical phase on choice of external knowledge transfer during the incremental phase (H2). Subsequently, external knowledge transfer is expected to have a positive effect on speed of incremental innovations (suggested by H3).

In-order to test all three hypotheses, we need to develop appropriate models for the underlying effects:

Effect of learning during the radical phase on speed of radical innovation (H1)

Effect of learning during the radical phase on choice of learning during the incremental phase (H2)

Effect of learning during the incremental phase on speed of incremental innovations (H3)

We now describe the econometric models used. For ease of exposition, we organize our discussion along the three expected effects:

Effect of learning during the radical phase on speed of radical innovation (H1)

We measure the speed of radical innovation as the time taken by an incumbent bank to introduce basic online transactional banking services. We model the effect of learning through internal knowledge creation during the radical phase on the time taken for this specific event (i.e. introduction of basic online transactional banking services) to occur. We do so by using survival analysis (Cox and Oakes, 1984). Survival analysis not only allows modeling the time taken for a specific event, it also allows us to model our uncensored data in which the specific event of online transactional banking occurs for all the banks in the sample. More precisely, we estimate the Cox proportional hazards regression model with time-independent covariates (Cox, 1972) and use the robust variance estimator (Lin and Wei, 1989) to control for firm specific unobserved heterogeneity. Specifically, we estimate:

$$\begin{aligned} h_i(t) = h_0(t)\exp(&\alpha_0 + \alpha_1 KnowledgeCreation_i + \alpha_2 Size_i \\ &+ \alpha_3 Charter_i + \alpha_4 Assetconcentration_i \\ &+ \alpha_5\ Rurality_i) \end{aligned} \quad (1)$$

where $h_i(t)$ = hazard or instantaneous probability of bank i introducing an online transactional banking service at time t, given that it had not introduced this service until time t; $h_0(t)$ = baseline hazard function; *Knowledge Creation* = learning through internal knowledge creation during the radical phase; the other variables, *Size, Charter, Asset concentration and Rurality* are control variables.

We further verify that our data satisfies the proportional hazards assumption for the covariates. We use the weighted Schoenfeld residual score test by Grambsch and Therneau (1994) since it has a relatively good power to detect non proportional hazards in many situations (Psersson, 2002). As a robustness check, we conduct these tests by replacing the current measure of size reported (i.e. log of employees in 1994) by another measure of size (i.e. deposits in 1994). We also check by replacing the current measure of size by a measure of profitability. We obtain similar and consistent results although the confidence intervals are larger in both cases compared to the model that uses log of employees in 1994 as a measure of size.

Effect of learning during the radical phase on choice of learning during the incremental phase (H2)

As discussed earlier, the effects underlying H2 and H3 together provide the indirect impact of learning through internal knowledge creation during the radical phase on speed of incremental innovations.

The generic equations for these effects are:

Knowledge Transfer = f (Knowledge Creation, Profitability, Charter, Asset Concentration, Rurality, Preparedness) (2)

Speed Incremental = f (Knowledge Transfer, Knowledge Creation, Profitability, Charter, Asset Concentration, Rurality, Preparedness) (3)

where *Knowledge Transfer* = external knowledge transfer during the incremental phase; *Knowledge Creation* = internal knowledge creation during the radical phase; *Speed Incremental* = speed of incremental innovations; the other variables, *Size, Charter, Asset concentration, Rurality and Preparedness* are control variables.

Equation 2 underlines H2, while Equation 3 underlines H3. The dependent variable, external knowledge transfer during the incremental phase in Equation 2 is an independent variable in Equation 3. This normally, requires simultaneous estimation of the two equations (Greene, 2003). However, the two equations together represent a recursive (or triangular) system of equations (see Kmenta, 1997). Hence, assuming that the error terms in both equations are uncorrelated, we can consistently estimate each equation separately rather than simultaneously.

Focusing on H2, we measure learning through external knowledge transfer during the incremental phase as the count of licensing agreements entered into by an incumbent bank until the end of 2003. We hypothesize that learning through internal knowledge creation during the radical phase affects this count of licensing agreements for an incumbent bank. In order to model this effect we need to account for the unique properties of count variables. Count variables are non-negative integers. Also, they are concentrated on a few small discrete values, skewed to the left and intrinsically heteroskedastic. We cannot use the ordinary least squares (OLS) method to model count variables since it results in biased, inefficient, and inconsistent estimates (Long, 1997). The Poisson regression is a more appropriate model than OLS in this context (Cameron and Trivedi, 1998).

Further in our modeling effort we need to account for two characteristics of our data on the dependent variable learning through 'external knowledge transfer during incremental phase':

1) The variance of this variable is five times larger than the mean (see Table 2). This indicates the possibility of over-dispersion, perhaps due to unobserved firm heterogeneity.
2) In 46 out of the 75 observations made, this variable has a score of zero.

So, our model needs to account for the excess zeros and over-dispersion. We estimate a zero-inflated Poisson (ZIP) model which takes into account both characteristics of our data (Long, 1997).

The basic Poisson model that we use is:

$$P(n_i) = \frac{\exp(-\lambda_i)\lambda_i^{n_i}}{n_i!} \qquad (4)$$

where n_i = external knowledge transfer during incremental phase measured as the licensing agreements count for firm i and the Poisson parameter λ_i is specified as:

$$\lambda_i = (\beta_0 + \beta_1 KnowledgeCreation_i + \beta_2 \Pr ofitability_i + \beta_3 Charter_i + \beta_4 AssetConcentration_i + \beta_5\ Rurality_i + \beta_6 \Pr eparedness_i)$$

where Knowedge Creation = internal knowledge creation during radical phase; the other variables, *Size, Charter, Asset concentration, Rurality and Preparedness* are control variables.

Further, we conduct the Vuong test (Greene, 2003) to statistically verify whether the zero-inflated model is more appropriate for our data than the non-zero inflated model. Further details regarding the outcome of this test are presented in the Results section.

Effect of learning during the incremental phase on speed of incremental innovations (H3)

As stated earlier, the generic equation for H3 is:

$$\textit{Speed Incremental} = f\,(\textit{Knowledge Transfer, Knowledge Creation, Profitability, Charter, Asset Concentration, Rurality, Preparedness}) \qquad (3)$$

where *Knowledge Transfer* = external knowledge transfer during the incremental phase; *Knowledge Creation* = internal knowledge creation during the radical phase; *Speed Incremental* = speed of incremental innovations; the other variables, *Size, Charter, Asset concentration, Rurality and Preparedness* are control variables.

We measure speed of incremental innovations as the count of the number of incremental innovations that an incumbent bank introduces on its website until the end of 2003. In order to model the effect of learning through external knowledge transfer during the incremental phase on the count of incremental innovations, we need to account for the Poisson distribution of the count dependent variable. We also need to account for the dual role of external knowledge transfer during the incremental phase. We know that external knowledge transfer is a dependent variable in Equation 2 but an independent variable in equation 3. Thus, external knowledge transfer is an endogenous variable i.e. it is correlated with the error term in Equation 3. We correct this by using the instrumental variables estimator (Wright, 1928 described in Stock and Watson, 2003).

We use an instrumental variable in place of the variable external knowledge transfer to estimate the coefficient. The criteria for selection of a valid instrumental variable are instrument relevance (i.e. the instrument should be correlated with the covariates), and instrument exogeneity (i.e. the instrument should not be correlated with the error term) (Stock and Watson, 2003). We use log of employees in 1994, which is a measure of size as the instrumental variable. The variable, log of employees in 1994 is correlated with external knowledge transfer (see Table 2), and we do not expect it to be correlated with the error term.

We gather from this discussion that estimation of H3 requires a model that accounts for a Poisson distribution and uses instrumental variables estimation. A generalized linear model (GLM) with instrumental variable (Hardin and Carroll, 2003) is suitable for this estimation. We specify the GLM using the log link and family distribution Poisson, as shown:

$$\begin{aligned} \ln(\text{SpeedIncremental}) = {} & \gamma_0 + \gamma_1 KnowledgeTransfer_i + \gamma_2 KnowledgeCreation_i \\ & + \gamma_3 \Pr ofitability_i + \gamma_4 Charter_i + \gamma_5 Assetconcentration_i + \gamma_6\ Rurality_i \\ & + \gamma_7 \Pr eparedness_i) \end{aligned} \qquad (5)$$

where *Knowledge Transfer* = external knowledge transfer during the incremental phase; *Knowledge Creation* = internal knowledge creation during the radical phase; *Speed Incremental* = speed of incremental innovations

Here, the instrumental variable is lnemp94 (i.e. the log of employees in 1994).

In the next section we discuss the results from our estimation of the selected models for each hypothesis.

Chapter 4: Results

Table 2 presents the descriptive statistics for the key variables. The independent and dependent variables have sufficient variance. The correlations provide face validity for Hypotheses 1, 2 and 3. The negative correlation between internal knowledge creation during the radical phase and speed of radical innovation is not significant (-0.08, $p>0.1$). The negative significant correlation between speed of radical innovation and speed of incremental innovations (-0.30, $p<0.01$) suggests support for our thesis that firms which are slow at radical innovation are fast at subsequent incremental innovations.

Table 3 presents the estimation results of the Cox proportional hazards model (Equation 1) for H1. Table 5 presents the estimation results of the zero-inflated Poisson regression (Equation 4). Table 6 presents the estimation results of the GLM with instrumental variables model (Equation 5) for H3. Finally, Table 7 presents the results of the additional analysis. We now describe the results of estimating the models for each of our hypotheses.

Effect of learning during the radical phase on speed of radical innovation (H1)

H1 argues that incumbent firms that learn through internal knowledge creation during the radical phase are likely to be slower at radical innovation than firms that learn through external knowledge transfer during the radical phase. In support of H1 (see Table 3), we find that learning through internal knowledge creation decreases the hazard rate for introduction of radical innovation (hazard coefficient = -0.28, $p<0.1$). Thus, incumbent firms that learn through internal knowledge creation take a longer time to introduce the radical innovation compared to incumbent firms that learn through external knowledge transfer during the radical phase. We also find that the covariates satisfy the assumption of proportionality. Table 4 shows that the test of proportional hazards assumption is not violated ($p>0.05$).

Effect of learning during the radical phase on choice of learning during the incremental phase (H2)

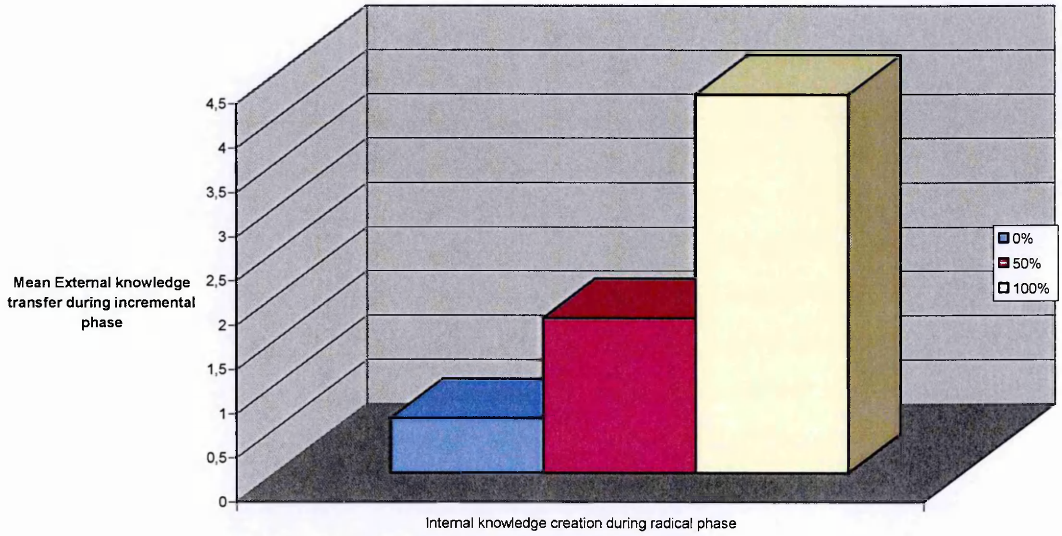
H2 argues that incumbent firms that learn through internal knowledge creation during the radical phase are more likely to use external knowledge transfer during the incremental phase. In support of H2 (see Table 5) we find that incumbent firms that learn through internal knowledge creation during the radical phase have 67% more licensing agreements during the incremental phase than incumbent firms that learn through external knowledge transfer during the radical phase (coefficient = 1.67[13], $p<0.01$).

We conclude that the ZIP model is more appropriate than the standard counterpart Poisson model because the Vuong score for ZIP is positive and greater than 1.96 (Long, 1997) ($z = 3.88$, $p<0.01$).

Figure 3 plots the data on external knowledge transfer during the incremental phase versus internal knowledge creation during the radical phase. The figure provides additional support for H2.

[13] Percentage of licensing agreements = (100 x (1.67-1) = 100 (0.67) = 67%

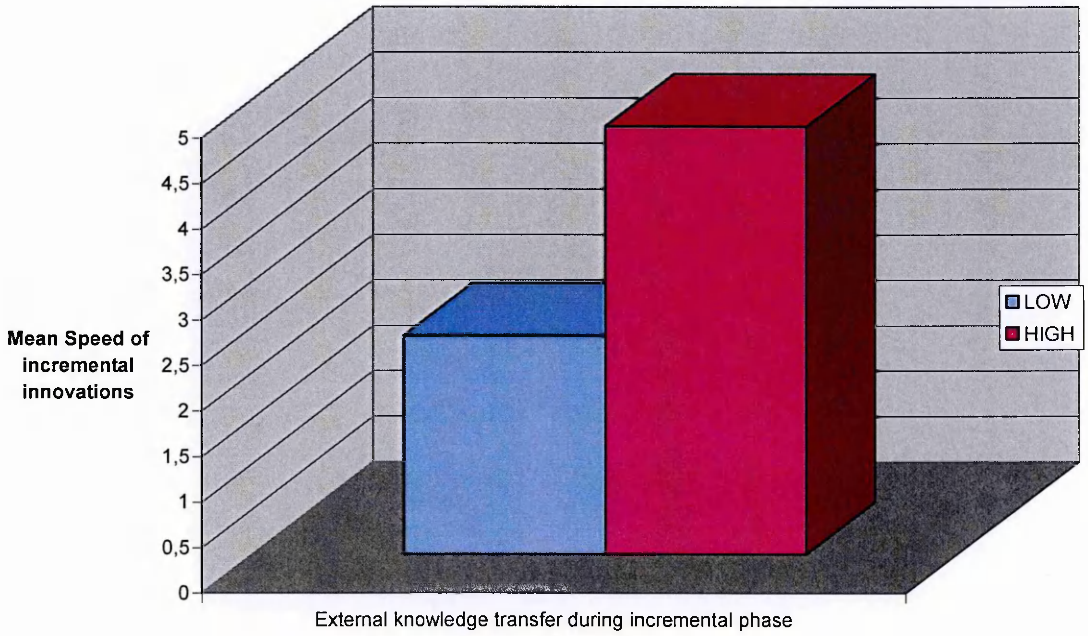
Figure 3: Effect of learning during the radical phase on choice of learning during the incremental phase



Effect of learning during the incremental phase on speed of incremental innovations (H3)

H3 argues that incumbent firms that learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase are likely to develop more incremental innovations compared to other incumbent firms. In partial support of H3 (see Table 6), we find that incumbent firms that learn through external knowledge transfer during the incremental phase develop more number of incremental innovations as compared to incumbent firms that learn through internal knowledge creation during the incremental phase (coefficient = 0.25, $p<0.01$). Figure 4 plots the data on speed of incremental innovations versus external knowledge transfer during the incremental phase. The figure provides some additional support for the hypothesized relationship. Further, in full support of H3 the combined results of H2 along with the above results show that incumbent firms that learn through internal knowledge creation during radical phase use learning through external knowledge transfer during the incremental phase. This in turn leads to the development of more incremental innovations.

Figure 4: Effect of learning during the incremental phase on speed of incremental innovations



Additional insight

A closer look at the results of the GLM with instrumental variables (see Table 6) provides additional insight over and above our hypotheses. It shows, on the one hand, that learning through internal knowledge creation during the radical phase has a negative *direct impact* on the speed of incremental innovations (coefficient = -0.35, $p<0.05$). On the other hand, combined results for H2 and H3 provide support for the positive *indirect impact* of learning through internal knowledge creation during the radical phase on the speed of incremental innovations.

This means that we cannot use the results supporting H1, H2 and H3 alone as evidence for our thesis that incumbent firms that learn through internal knowledge creation during the radical phase are slow at radical innovation but fast at incremental innovation. *Support for this thesis requires additional analysis that shows the positive indirect effect of* *internal knowledge creation during radical phase to be greater in magnitude than the negative direct effect of internal knowledge creation during radical phase on speed of incremental innovations.* This additional analysis is discussed below.

Additional analysis

We calculate and compare the magnitude of the direct and indirect effects statistically by simultaneously solving the generic equations (2) and (3) which underline H2 and H3. Three-stage least squares estimation (3SLS) (Kmenta, 1997; Greene, 2003) is suitable for this purpose. Specifically, we simultaneously estimate the following two equations that underline H2 and H3:

$$\begin{aligned}\text{KnowledgeTransfer*} = \delta_0 + \delta_1 KnowledgeCreation_i * + \delta_2 \Pr ofitability_i * + \delta_3 Charter_i * \\ + \delta_4 Assetconcentration_i * + \delta_5 Rurality_i * + \delta_6 \Pr eparedness_i * + \varepsilon_i\end{aligned} \quad (6)$$

$$\begin{aligned}\text{SpeedIncremental} * = \kappa_0 + \kappa_1 KnowledgeTransfer_i * + \kappa_2 KnowledgeCreation_i * \\ + \kappa_3 \Pr ofitability_i * + \kappa_4 Charter_i * + \kappa_5 Assetconcentration_i * \\ + \kappa_6 Rurality_i * + \kappa_7 \Pr eparedness_i * + \mu_i\end{aligned} \quad (7)$$

where *Knowledge Transfer* = external knowledge transfer during the incremental phase; *Knowledge Creation* = internal knowledge creation during the radical phase; *Speed Incremental* = speed of incremental innovations; the other variables, *Size, Charter, Asset concentration, Rurality and Preparedness* are control variables.

Both of these equations have dependent variables that are count data and hence, are only approximately continuous. Though this violates the assumption of linearity within the 3SLS model specification, it is an approach used by Powell et al. (1996) and remains a useful way of comparing direct and indirect effects. Other count data models for endogeneity are still in their infancy and do not exactly coincide with our problem (see Blundell et al., 2002; Windmeijer and Santos, 1997; Mullahy, 1997).

Further, simultaneous estimation of Equations 6 and 7 requires them to be identified. Currently, Equation 6 is under identified. We use a measure of size (log of employees in 1994) as an additional exogenous variable during the 3SLS estimation so that the system of equations is just identified. We use standardised values for all variables during this estimation so that the coefficients are readily comparable.

Results of additional analysis

The results of this 3SLS estimation are provided in Tables 7a and 7b. The direct effect of internal knowledge creation during the radical phase on speed of incremental innovations is -0.49 ($p<0.01$) (See Table 7b). The calculation of the indirect effect of internal knowledge creation during the radical phase on speed of incremental innovations involves combination of:

i) The effect of internal knowledge creation during radical phase on external knowledge transfer during incremental phase (0.38, $p<0.01$) (see Table 7 a), and

ii) The subsequent effect of external knowledge transfer during incremental phase on speed of incremental innovations (1.50, $p<0.01$) (see Table 7b).

Thus, the indirect effect of internal knowledge creation during the radical phase on speed of incremental innovations is a combination: 0.38 * 1.50 = 0.57.

We can now compare the magnitude of the direct and indirect effects. The positive indirect effect is 0.57, which is greater in magnitude than the negative direct effect of -0.49. This shows that the overall effect of internal knowledge creation during the radical phase on speed of incremental innovations is positive and significant. Results for H1, H2, H3 along with additional analysis provides support for our thesis that incumbent firms which learn through internal knowledge creation during the radical phase are slower at radical innovation but faster at incremental innovations.

Chapter 5: Discussion

In this study, we highlight the path-dependent nature of modes of learning during the innovation process and their role in influencing the speed of innovation over time. We argue that the path-dependent sequence of combination of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase leads to slow radical innovation but fast incremental innovations. On the other hand, any other sequence of combination starting with external knowledge transfer during the radical phase leads to relatively fast radical innovation but slow incremental innovations. These arguments explain how incumbent firms that are slow initially can be faster later at innovation over time relative to incumbent firms that are fast initially. Contrary to popular belief the arguments indicate that incumbent firms can either be fast at initial radical innovation or fast at subsequent incremental innovations, but not fast at both. Overall, the thesis indicates that a focus on being fast initially is not as beneficial in the long term as is a focus on initial internal learning.

The results support our central thesis that incumbent firms which learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase are slower at radical innovation but faster at incremental innovations compared to other firms. We find evidence for the path-dependent effect of internal knowledge creation during the radical phase on choice of external knowledge transfer during the incremental phase (see results for H2). We find that internal knowledge creation during the radical phase leads to slow radical innovation relative to external knowledge transfer during the radical phase (see results for H1). Finally, we show that the path-dependent combination of internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase leads to more incremental innovations relative to other combinations of internal knowledge creation and external knowledge transfer during the innovation process (see results for H2, H3 and additional analysis).

The results are applicable across varied sectors of activity when the sector is faced by a radical innovation in IT-based service. The sectors of activity could range from pure service industries to manufacturing goods industries to retailers. For example, incumbent firms in services industry like retail banking are faced by the radical innovation of online banking (Chandy et al., 2003). Similarly, incumbent firms that manufacture consumer goods like photographic silver halide films and cameras are faced by the radical innovation of digital photography (Santi, 2003). So the common criteria necessary across industries for the findings to be applicable is the introduction of a radical innovation in IT-based services.

The results are valid for certain firms in the business-to-business as well as the business-to-consumer context. These firms should be large incumbent firms that introduce the radical innovation during the radical phase. Hence, the results are not valid for new entrants or small incumbent firms or large incumbent firms that introduce the radical innovation only after the emergence of a dominant design of the radical innovation.

Implications for practice

This study offers practical insights into competition among incumbent firms at innovating over time. In doing so, we view innovation as a process. This is in contrast with the popular view of innovation as an output i.e. a single product or a service (see BusinessWeek, 2006).

More precisely, our study provides three clear strategic guidelines for practice so that incumbent firms can be faster than their competition at innovation over time.

Develop internally: We advise incumbent firms to use in-house technology development during the radical phase despite the resulting decrease in speed of radical innovation in the process. Our advice is contrary to the conventional wisdom that firms should form licensing agreements since they lead to faster innovation. For example, a recent cover story in BusinessWeek (2006) entitled, "Speed Demons," quotes Azim Premji, Chairman of the Indian outsourcing firm, Wipro as saying "Our clients are under a lot of pressure to get new products faster into the market. Their core employment isn't adequate for it, so they are looking for partners who can do it for them."

In this study, we contend that incumbent firms which license are faster at radical innovation, but they fail to develop internal knowledge in the process. In contrast, incumbent firms that develop the technology in-house are slower at radical innovation, but they develop internal knowledge. We argue that developing internal knowledge initially is essential for competing at innovation in the long term because it develops important capabilities. Hence, we recommend incumbent firms to use in-house technology development during the radical phase instead of licensing agreements.

Develop internally then license: We show that incumbent firms which use in-house technology development during the radical phase form many licensing agreements during the incremental phase. We argue that such incumbent firms develop internal knowledge which is useful for efficiently adopting licensed components during the incremental phase. This ultimately leads to the use of many licensing agreements during the incremental phase. On the other hand, we show that incumbent firms that use licensing during the radical phase can form limited licensing agreements during the incremental phase. We argue that such incumbent firms do not develop internal knowledge. Hence, they are 'locked out' (Cohen and Levinthal, 1990) and unable to efficiently adopt licensed components during the incremental phase. This limits the use of licensing agreements during the incremental phase.

Our findings are in contrast to the current empirical research on path-dependence between modes of technology acquisition which expects firms that use one mode (say, licensing agreements) initially to continue using the same mode later (Hagedoorn and Duysters, 2002). Hence, in contrast to past research we advise incumbent firms to follow the path of in-house technology development during the radical phase followed by licensing agreements during the incremental phase instead of any other possible path.

Live with trade offs: We point out that incumbent firms are faster either at radical innovation or at incremental innovations, but not faster at both. We empirically demonstrate that incumbent firms that use the path of in-house technology development during the radical phase followed by licensing during the incremental phase will be relatively slow at radical innovation but fast at incremental innovations. On the other hand, incumbent firms that use either of the following two paths will be relatively fast at radical innovation but slow at incremental innovations. These paths involve licensing during theradical phase followed by in-house technology development during the incremental phase, or licensing during both phases of the innovation process.

These findings have two implications for practice. First, contrary to common belief licensing is beneficial to speed of innovation in the long term only when used at the right time and in the right sequence. This has further implications for resource allocation strategy of firms. Second, these results indicate that past literature and conventional wisdom that expect firms to be always fast at innovation (e.g., Robinson and Fornell, 1985; Robinson, 1988; BusinessWeek, 2006; Kitcho, 2001) are unrealistic in their expectation.

Hence, incumbent firms should be willing to trade-off short term gains obtained through the use of licensing agreements in the radical phase and instead choose to use in-house technology development during the radical phase so as to win the innovation race in the long term.

Implications for research

Our study uses the knowledge-based view of the firm to advance theoretical knowledge regarding the nature of learning and develop conceptual understanding of this view in the context of dynamic environments.

First, we use the knowledge-based view of the firm to conceptually and empirically reveal the nature of path-dependency in learning during the innovation process. Past literature has failed to study path dependency in learning during the innovation process (see Cohen and Levinthal, 1994; Pisano, 1990; Hagedoorn and Duysters, 2002). Hence, current knowledge on path dependency in the innovation context would assume that firms which use one mode of learning during the radical phase will continue to use the same mode of learning during the incremental phase. Instead, we develop conceptual arguments based on interchange between codified and un-codified knowledge (Nonaka, 1994) to show that radical and incremental phases require different modes of learning. Hence, contrary to some past empirical research, (e.g., Pisano, 1990) we are able to show that incumbent firms that learn through internal knowledge creation during the radical phase are more likely to learn through external knowledge transfer during the incremental phase than incumbent firms that learn through external knowledge transfer during the radical phase.

Second, we build on the dynamic theory of organizational knowledge creation (Nonaka, 1994) to conceptually reveal the dynamics of learning during the innovation process. Past literature takes a static view of learning and focuses on combining modes of learning at a point in time in the context of innovations (e.g. Rosenkopf and Nerkar, 2001; Tsai, 2001; Prabhu et al., 2005). In contrast, we take a dynamic view and provide sequential combinations of modes of learning or knowledge creation paths through which incumbent firms can learn. In so doing, we map the interchange between un-codified and codified knowledge for each path. Finally, we develop arguments based on this interchange between codified and un-codified knowledge to explain the impact of different knowledge creation paths on the speed of radical and incremental innovations.

Third, we use the knowledge-based view of the firm to develop the related but broader evolutionary theory of the firm (Teece and Pisano, 1994; Teece et al., 1997; Barney, 2001; Levinthal and Myatt, 1994; Karim and Mitchell, 2000). Past literature on evolutionary theory of the firm has regarded knowledge creation processes to be a 'dynamic capability' (Zollo and Winter, 2002; Eisenhardt and Martin, 2000, Teece et al., 1997). Researchers have stressed the need to understand better the nature of dynamic capabilities like knowledge creation processes, and how their effectiveness changes over time (Rothaermel, 2001). Barney et al. (2001, p.632) have also pointed out that, "Our understanding of dynamic capabilities is limited and thus these capabilities, and the way they can generate competitive advantages, deserve a great deal of empirical attention". We address this gap in the literature by empirically showing that the knowledge creation process within a firm has a changing effect on innovation over time. Incumbent firms that learn through internal knowledge creation during the radical phase followed by external knowledge transfer during the incremental phase have a negative effect on speed of radical innovation but a positive effect on speed of incremental innovations. Similarly, incumbent firms that learn through external knowledge transfer during the radical phase followed by internal knowledge creation during the incremental phase have a positive effect on speed of radical innovation but a negative effect on speed of incremental innovations. Thus, by using the knowledge-based view of the firm, we shed light on the nature of dynamic capabilities and hence, develop the evolutionary theory of the firm.

Limitations and suggestions for future research

Our study is not without limitations. There are conceptual as well as empirical limitations that can be addressed in future studies. First, we do not consider learning through external un-codified knowledge transfer in the path-dependent sequence of modes of learning during the innovation process. It is likely that at a point in time incumbent firms would require to learn through external un-codified knowledge transfer (see Cavusgil et al., 2003; Agrawal, 2006). Further research in path-dependency during the innovation process should consider the particular sequence in which choice of learning through external un-codified knowledge is likely to occur.

In addition, certain aspects of the learning path during the innovation process remain unstudied. Our study explains the path-dependent choice of mode of learning during the incremental phase but not for the radical phase. An explanation for choice of mode of learning during the radical phase is missing in this study. Future research in this direction would provide more insight into the path-dependent nature of learning during the innovation process.

Second, this study focuses on surviving incumbent firms in a single industry. This raises two issues. Regarding the inclusion of non-survivors in our study, Golder and Tellis (1993) have pointed out that research on effect of speed of innovation on market share needs to account for survivors as well as non-survivors. This is because firms that are fast at radical innovation are expected to have higher rates of non-survivors. We do not expect a significant change in our results if we include non-survivors in the sample. In fact we expect an inclusion of non-survivors to strengthen our results. Incumbent firms that are fast at radical innovation are expected to have more non-survivors than firms that are slow at radical innovation. This should reinforce our results in which incumbent firms that are fast are radical innovation are expected to be slower at incremental innovations over time compared to firms that are slow at radical innovation

In addition, we study the development of a single radical innovation in IT-based services i.e. online banking in the retail banking industry. This means our empirical context is limited to a single industry. However, it is possible to generalize the results from online banking to other services or manufacturing industries that have faced radical innovation in IT-based services. This view is shared by previous papers that study innovations in a single industry (e.g. Prabhu et al., 2005; Chandy et al., 2003; Chandy and Tellis, 1998; Shankar et al., 1998). Nevertheless, future research can look across industries and across nations so as to enhance the external validity and verify the generalizability of our results.

Finally, we used a linear 3SLS model for additional analysis which might be considered inappropriate because of the count nature of our dependent variables. Nonetheless, we performed this analysis by assuming that the dependent variables are approximately continuous. Future research could use more sophisticated nonlinear modelling which is currently in its infancy (see Blundell et al., 2002; Windmeijer and Santos, 1997; Mullahy, 1997).

Conclusion

Our study asks: how should incumbent firms innovate in IT-based services in the long term? We show that incumbent firms should be slow and steady during the innovation race instead of focusing on being fast at initial radical innovation. Specifically, we find that incumbent firms that learn through internal knowledge creation initially are slow at initial radical innovation but fast at subsequent incremental innovations. On the other hand, incumbent firms that learn through external knowledge transfer initially are fast at initial radical innovation but are unable to be fast at subsequent incremental innovations. This contradicts the common research and the prevailing belief among managers that being fast at initial radical innovation is always good. We advise incumbent firms to focus on internal learning initially and remain content with being a tortoise rather than a hare in the long innovation race.

Table 1

Measures & Sources

Constructs	*Conceptual Variables*	*Measure*	*Data Sources*
Innovation during radical phase	Speed of radical innovation	Number of months to introduce basic online transactional banking after 1st May 1995	Internet Archives Thomson Directory of Online Banking
Innovation during incremental phase	Speed of incremental innovations	Number of incremental innovations	Browsing of Banks' Websites in December 2003 News Archives on Banks' Websites News Archives on Technology Vendors' Websites
Learning during incremental phase	External knowledge transfer during incremental phase	Number of licensing agreements	Bank Systems and Technology SDC Platinum Factiva News Archives on Banks' Websites News Archives on Technology Vendors' Websites
Learning during radical phase	Internal knowledge creation during radical phase	Presence of in-house or licensed web servers and online banking platform	Inter NIC Online Banking Report Telephonic Survey
Control Variables	Size, Profitability, Charter, Asset concentration, Rurality, Preparedness	Log of employees, Deposits; Log of ROA, National vs. State Charter, Commercial vs. Consumer asset specialization, Average degree of rurality, Number of months to register domain name after 2nd February, 1991	FDIC Economic Research Service Website Inter NIC

	Deviation)	innovation	incremental innovations	knowledge transfer	knowledge creation	Size	Profitability	Charter	Concentration	Rurality	Preparedness
Speed of radical innovation	40.50 (10.23)	1.00	-0.30***	-0.49***	-0.08	-0.40***	-0.11	0.13*	-0.10	-0.03	0.48***
Speed of incremental innovations	2.92 (1.94)	-0.30***	1.00	0.50***	0.10	0.57***	0.02	-0.14*	0.17**	0.024	-0.46***
External knowledge transfer	1.27 (2.47)	-0.49***	0.50***	1.00	0.39***	0.66***	-0.03	-0.23**	0.27***	-0.14*	-0.51***
Internal knowledge creation	0.54 (0.65)	-0.08	0.10	0.39***	1.00	0.30***	0.25**	-0.27***	0.10	-0.09	-0.14
Size	6.63 (1.82)	-0.40***	0.57***	0.66***	0.30***	1.00	-0.02	-0.16*	0.24**	-0.06	-0.55***
Profitability	0.12 (0.52)	-0.11	0.02	-0.03	0.25**	-0.02	1.00	-0.13	0.18**	0.16*	0.12
Charter	0.52 (0.50)	0.13*	-0.14*	-0.23**	-0.27***	-0.16*	-0.13	1.00	-0.13	0.50	0.11
Asset Concentration	0.35 (0.48)	-0.10	0.17**	0.27***	0.10	0.24**	-0.18**	-0.13	1.00	-0.08	-0.17
Rurality	1.87 (1.63)	-0.03	0.02	-0.14*	-0.09	-0.06	0.16*	0.05	-0.08	1.00	0.11
Preparedness	49.2 (27.84)	0.48***	-0.46***	-0.51***	-0.14	-0.55***	0.12	0.11	-0.17	0.11	1.00

Note:***p<0.01, **p<0.05, *p<0.1

Table 3

Effect of Internal Knowledge Creation during Radical Phase on Speed of Radical Innovation (H1)

Cox proportional hazards model

Independent Variable	***Robust Coefficient (Standard Error)***
Internal knowledge creation during radical phase	-0.28* (0.15)
Size (lnemp94) [a]	0.19*** (0.05)
Charter	0.39* (0.21)
Asset concentration	0.04 (0.20)
Rurality	-0.09 (0.06)
N Log Pseudo-likelihood Wald χ^2	77 -260.35 16.43***

Note: [a]Replacing by Profitability & other Size measures gives similar results
***p<0.01, **p<0.05, *p<0.1

Table 4
Weighted Schoenfeld Residual Score Test

Test of proportional hazards assumption

Independent Variable	*Chi²*
Internal knowledge creation during radical phase	1.26
Size (lnemp94)	1.98
Charter	4.17**
Asset concentration	0.69
Rurality index	0.65
Global test	8.01

Note: Robust variance-covariance matrix used
***p<0.01, **p<0.05, *p<0.1

Table 5

Effect of Internal Knowledge Creation during Radical Phase on External Knowledge Transfer during Incremental Phase (H2)

Zero-Inflated Poisson Regression

Independent Variable	*IRR (Standard Error)*
Internal knowledge creation during radical phase	1.67* (0.51)
Profitability (lnroa94)	0.70 (0.19)
Charter	1.89** (0.56)
Asset concentration	0.89 (0.25)
Rurality	1.08 (0.14)
Preparedness	0.99 (0.00)
N	75
Log Likelihood	-90.98
LR χ^2	34.20***

Note : ***p<0.01, **p<0.05, *p<0.1

Table 6

Effect of External Knowledge Transfer during Incremental Phase on Speed of Incremental Innovations (H3)

GLM with IV

Independent Variable	*Coefficient (Standard Error)*
External Knowledge Transfer during incremental Phase	0.25*** (0.07)
Internal Knowledge Creation during radical Phase	- 0.35** (0.15)
Profitability (lnroa94)	-0.02 (0.18)
Charter	-0.10 (0.14)
Asset concentration	0.16 (0.16)
Rurality	0.00 (0.05)
Preparedness	0.00 (0.00)
Constant	0.85* (0.47)
N	75
Deviance	83.39

Note : ***p<0.01, **p<0.05, *p<0.1

Table 7 a

Direct and Indirect Effect of Internal Knowledge Creation during Radical Phase on Speed of Incremental Innovations

3SLS: Equation 6: Dependent variable is external knowledge transfer during incremental phase

Independent Variable	*Standardised Coefficient (Standard Error)*
Internal knowledge creation during radical phase (Standardized value)	0.38*** (0.10)
Profitability (lnroa94) (Standardized value)	-0.14 (0.13)
Charter (Standardized value)	0.05 (0.09)
Asset concentration (Standardized value)	-0.15 (0.09)
Rurality index (Standardized value)	-0.02 (0.10)
Preparedness (Standardized values)	-0.42*** (0.09)
Constant	0.03 (0.09)
N	75
R^2	0.41

Note : ***p<0.01, **p<0.05, *p<0.1

Table 7 b

Direct and Indirect Effect of Internal Knowledge Creation during Radical Phase on Speed of Incremental Innovations

3SLS: Equation 7: Dependent variable is speed of incremental innovations

Independent Variable	*Standardised Coefficient (Standard Error)*
Internal knowledge creation during radical phase (Standardized value)	-0.49*** (0.14)
External knowledge transfer during incremental phase (Standardized value)	1.50*** (0.21)
Profitability (lnroa94) (Standardized value)	0.02 (0.15)
Charter (Standardized value)	-0.11 (0.10)
Asset concentration (Standardized value)	0.17 (0.11)
Rurality index (Standardized value)	0.001 (0.11)
Preparedness (Standardized value)	0.20 (0.13)
Constant	0.04 (0.10)
N	75
R^2	-0.62

Note : ***p<0.01, **p<0.05, *p<0.1

References

References

Abernathy, W. and Utterback, J. (1978), "Patterns of Industrial Innovation," *Technology Review,* 80: 97–107.

Afuah, A. (1998). *Innovation Management: Strategies, Implementation, and Profits.* Oxford University Press, New York.

Aghion, P. and Howitt, P. (1992), "A Model of Growth Through Creative Destruction," *Econometrica,* 60(2): 323-351.

Agrawal, A. (2006), "Engaging the Inventor: Exploring Licensing Strategies for University Inventions and the Role of Latent Knowledge," *Strategic Management Journal*, 27: 63-79.

Ahuja, G. and Lampert, C. (2001), "Entrepreneurship in the Large Corporation: A Longitudinal Study of How Established Firms Create Breakthrough Inventions," *Strategic Management Journal,* 22: 521-543.

American Bankers Insurance Association (2006), "The Benefits of Charter Choice," Available on http://www.aba.com/NR/rdonlyres, (Accessed on 6th Sept., 2006).

Anand, B. and Khanna, T. (2000), "Do Firms Learn to Create Value? The Case of Alliances." *Strategic Management Journal,* 21(3): 295-315.

Anderson, P. and Tushman, M. (1990), "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change," *Administrative Science Quarterly,* 35: 604-633.

Arora, A. and Gambardella, A. (1994), "Evaluating Technological Information and Utilizing It: Scientific Knowledge, Technological Capability, and External Linkages in Biotechnology," *Journal of Economic Behaviour and Organization,* 24: 91-114.

Arthur, B. (1990), "Positive Feedbacks in the Economy," *Scientific American*, 262: 92-99.

Banks, E. (2001), *e-Finance: The Electronic Revolution*, John Wiley & Sons, New York.

Barney, J. (2001), "Resource-Based Theories of Competitive Advantage: A Ten-Year Retrospective on the Resource-Based View," *Journal of Management*, 27: 643-650.

Barney, J., Wright, M. and Ketchen, D. Jr. (2001). "The Resource-Based View of the Firm: Ten Years after 1991," *Journal of Management*, 27, 625-641.

Birkinshaw, J. and Gibson, C. (2004), "Building Ambidexterity into an Organization," *MIT Sloan Management Review*, Summer, 47-55.

Blaha, M. (1998), "On Reverse Engineering of Vendor Databases," *Working Conference on Reverse Engineering*, Honolulu, Hawaii, October.

Blundell, R., Griffth, R. and Windmeijer, F. (2002), "Individual Effects and Dynamics in Count Data Models," *Journal of Econometrics*, 108: 113-131.

Bond, R. and Lean, D. (1977), "Sales, Promotion and Product Differentiation in Two Prescription Drug Markets," Washington, DC: U.S. Federal Trade Commission.

Borenstein, S. (1990), "Airline Mergers, Airport Dominance, and Market Power," *American Economic Review Papers and Proceedings*, 80(2): 400-404.

Borenstein, S. (1991), "The Dominant-Firm Advantage in Multi-Product Industries: Evidence from the U.S. Airlines," *Quarterly Journal of Economics*, 106(4): 1237-1266.

BusinessWeek (2006), "Speed Demons," Available on http://www.businessweek.com/magazine/content/06_13/b3977001.htm, (Accessed on 27th April 2006).

Business Wire (1996), "U.S. Robotics Launches Breakthrough Pocket-Size Connected Organizer for PC Users," http://www.palminfocenter.com/news/8493/pilot-1000-retrospective/, (Accessed on 20th Feb 2006).

Cameron, C. and Trivedi, P. (1998), *Regression Analysis of Count Data*. Cambridge University Press.

Carlson, J., Furst, K., Lang, W. and Nolle, D. (2001), "Internet Banking: Market Developments and Regulatory Issues," presented to Society of Government

Economists Conference 2000: *The New Economy: What Has Changed and the Challenges for Economic Policy*, Washington, D.C.

Cassiman, B. and Veugelers, R. (2002), "Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition and Co-operation in R&D," *Working Paper*.

Cassiman B. and Veugelers, R. (2001), "R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium," forthcoming *American Economic Review*.

Cavusgil, S., Calantone, R. and Zhao, Y. (2003), "Tacit Knowledge Transfer and Firm Innovation Capability," *Journal of Business and Industrial Marketing*, 18(1): 6-21.

Chandy, R., Prabhu, J. and Antia, K. (2003), "What Will the Future Bring? Dominance, Technology Expectations, and Radical Innovation," *Journal of Marketing*, 67: 1-18.

Chandy, R. and Tellis, G. (1998), "Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize," *Journal of Marketing Research*, 35 (November): 474-487.

Choo, C. (1998), *The Knowing Organization*, Oxford University Press, New York, NY.

Christensen, C. (1993), "The Rigid Disk Drive: A History of Commercial and Technological Turbulence," *Business History Review*, 67: 531-588.

Cohen, W. and Levinthal, D. (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35: 128-152.

Cohen, W. and Levinthal, D. (1994), "Fortune Favors the Prepared Firm," *Management Science*, 40(2): 227-251.

Cox, D. (1972), "Regression Models and Life Tables (with Discussion)," *Journal of the Royal Statistical Society*, Series B 34: 187-220.

Cox, D. and Oakes, D. (1984), *Analysis of Survival Data*, New York: NY: Chapman and Hall.

Davis, S. and Meyer, C. (1998), *BLUR: The Speed Of Change In A Connected Economy*, Ernst & Young Center for Business Innovation, Perseus Books, Reading, Massachusetts.

Dodge, D. (2005), "Innovate or Imitate…Fame or Fortune?" Available on http://dondodge.typepad.com/the_next_big_thing/2005/10/innovate_or_imi.html, (Accessed on 19th July, 2006).

Dosi, G. (1982), "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technological Change," *Research Policy*, 11: 147-162.

Dawson, G., Maureen, M. and Anand, P. (2006), *Economics and Economic Change: Microeconomics*, 2nd ed. Prentice Hall.

Eathington, L. and Swenson, D. (2002), "Information Technology Employment Growth in Iowa, 1992-2000," Available on http://www.seta.iastate.edu/industry/publications/ITStudy.pdf, (Accessed on 30/5/2007).

Eisenhardt K. and Tabrizi B. (1995), "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry," *Administrative Science Quarterly,* 40(1): 84–110.

Eisenhardt, K. and Martin, J. (2000), "Dynamic Capabilities: What are they?," *Strategic Management Journal*, 21: 1105-1121.

European Council (2000), Lisbon; Available on http://ec.europa.eu/education/policies/2010/ et_2010_en.html, (Accessed on 30th May 2007).

Foss, N. (1996), "Knowledge-Based Approaches to the Theory of the Firm: Some Critical Comments," *Organization Science*, 7 (5), Sep. - Oct.: 470-476.

Furst, K., Lang, W. and Nolle, D. (2002), "Internet Banking: Developments and Prospects," Program on Information Resources Policy, Harvard University.

Furst, K., Lang, W. and Nolle, D. (2000), "Who Offers Internet Banking?" Office of the

Comptroller of the Currency, *Quarterly Journal*, 19(2), June: 29-48.

Garcia, R. and Calantone, R. (2002), "A Critical Look at Technological Innovation Typology and Innovativeness Terminology: A Literature Review," *The Journal of Product Innovation Management*, 19: 110-132.

Golder, P. and Tellis, G. (1993), "Pioneer Advantage: Marketing Logic or Marketing Legend?," *Journal of Marketing Research*, 30 (May): 158-170.

Grambsch, P. and Therneau, T. (1994), "Proportional Hazards Tests and Diagnostics Based on Weighted Residuals," *Biometrika*, 81: 515-526.

Granstrand, O., Patel, P. & Pavitt, K. (1997), "Multi-technology Corporations: Why They Have 'Distributed' Rather Than 'Distinctive Core' Competencies," *California Management Review*, 39(4): 8-25.

Grant, R. (1996), "Toward a Knowledge-Based Theory of the Firm," *Strategic Management Journal*, 17, Special Issue: Knowledge and the Firm: 109-122.

Grant, R. (1998), *Contemporary Strategy Analysis*, Malden, Massachusetts: Blackwell.

Greene, W. (2003), *Econometric Analysis*, 5th ed. Upper Saddle River, NJ: Prentice-Hall.

Greenspan, A. (1997), "Financial Reform and the Importance of the State Charter," Annual Meeting of State Bank Supervisors, San Diego, California, Available on http://www.federalreserve.gov/BoardDocs/Speeches/1997/19970503.htm, (Accessed on 6th Sept., 2006).

Greenspan, A. (1998), "Is there a new economy? ," *California Management Review*, 41 (1): 74–85.

Grossman, G. and Helpman, E. (1991), "Quality Ladders in the Theory of Growth," *Review of Economic Studies,* 58: 43-61.

Gupta, M., Rao, H. and Upadhyaya, S. (2004), "Electronic Banking and Information Assurance Issues: Survey and Synthesis," *Journal of Organizational and End User Computing,* Special Issue on Information Assurance and Security, Idea Group of Publishing, 16(3): 1-21.

Hagedoorn, J. and Duysters, G. (2002), "External Sources of Innovative Capabilities: The Preference for Strategic Alliances or Mergers and Acquisitions," *Journal of Management Studies*, 39(2): 167-188.

Hall, D., Whitmire, R., Hall, S. and Knight, L. (2002), "The Trend Toward Online Banking Services by Brick-and-Mortar Institutions: The Last Five Years," in *'Internet Management Issues: A Global Perspective'* by John D. Haynes, Idea Group Publishing.

Hansen, M. (1999), "The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organization Subunits," *Administrative Science Quarterly*, 44(1): 82-111.

Hardin, J. and Carroll, R. (2003), "Variance Estimation for the Instrumental Variables Approach to Measurement Error in Generalized Linear Models," *The Stata Journal*: 1-10.

Henderson, R. and Clark, K. (1990). "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly*, 35: 9-30.

Hill, C. and Rothaermel, F. (2003), "The Performance of Incumbent Firms in the Face of Radical Technological Innovation," *Academy of Management Review*, 28(2): 257-274.

Jones, N. (2003), "Competing After Radical Technological Change: The Significance of Product Line Management Strategy," *Strategic Management Journal*, 24: 1265-1287.

Kalyanaram, G. and Urban, G. (1992), "Dynamic Effects of the Order of Entry on Market Share, Trial Penetration, and Repeat Purchases for Frequently Purchased Consumer Goods," *Marketing Science*, 11 (Summer): 235-250.

Kalyanaram, G., Robinson, W. and Urban, G. (1995), "Order of Market Entry: Established Empirical Generalizations, Emerging Empirical Generalizations, and Future Research," *Marketing Science*, 14(3): 212-221.

Karim, S. and Mitchell, W. (2000), "Path-Dependent and Path-Breaking Change: Reconfiguring Business Resources Following Acquisitions in the U.S. Medical Sector, 1978-1995," *Strategic Management Journal*, 21(10): 1061-1081.

Keeton, W. (2001), "The Transformation of Banking and Its Impact on Consumers and Small Businesses," *Economic Review*, 86(1).

Kerin, R., Varadarajan, P. and Petrson, R. (1992), "First-Mover Advantages: A Synthesis, Conceptual Framework and Research Propositions," *Journal of Marketing*, 56 (October): 33-52.

Kitcho, C. (2001), *From Idea to Launch at Internet Speed: How to Identify and Develop Profitable Organizations*, Pele Publications.

Klepper, S. (1997), "Industry Life Cycles," *Industrial and Corporate Change*, 6: 145-181.

Kmenta, J. (1997), *Elements of Econometrics*, Ann Arbor: University of Michigan Press.

Koblentz, E., "The Evolution of the PDA," Available on http://www.snarc.net, (Accessed on 20th Feb, 2006).

Kumar, C. (2006), "Palm's Growth Strategies," European Case Clearing House, Reference No. 306-277-1.

Leonard, D. and Sensiper, S. (1998), "The Role of Tacit Knowledge in Group Innovation," *California Management Review*, 40(3): 112-132.

Levinthal, D. and Myatt, J. (1994), "Co-evolution of Capabilities and Industry: The Evolution of Mutual Fund Processing," *Strategic Management Journal*, 15: 45-62.

Lieberman, M. and Montgomery, D. (1988), "First-Mover Advantages," *Strategic Management Journal*, 9 (Summer): 41-58

Lin, D. and Wei, L. (1989), "The Robust Inference for the Cox Proportional Hazards Model," *Journal of the American Statistical Association*, 84: 1074-1078.

Lloyd, B. (2004), "Book Review: Strategic Management in the Knowledge Economy," by Leibold, M., Probst, G., and Gibbert, M. (2002), Wiley," *Long Range Planning*, 37: 103-114.

Long, S. (1997), *Regression Models for Categorical and Limited Dependent Variables,* Thousand Oaks, CA: Sage Publications.

Longworth, D. (2006), Remarks, *Conference of the Association of Economists of Quebec,* Quebec, Available on http://www.bankofcanada.ca/en/speeches/2006/sp06-8.html , (Accessed on 20th July, 2006).

Madhavan, R. and Grover, R. (1998), "From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management," *Journal of Marketing*, 62: 1-12.

Malerba, F. (1992), "Learning by Firms and Incremental Technical Change," *The Economic Journal*, 102: 845-859.

March, J. (1991), "Exploration and Exploitation in Organizational Learning," *Organization Science,* 2(1): 71-87.

McCullagh, P. and Nelder, J. (1989), *Generalized Linear Models*, 2nded. London: Chapman & Hall.

McGahan, A., Argyres, N. and Baum, J. (2004), "Context, Technology and Strategy: Forging New Perspectives on the Industry Life Cycle," in: *Business Strategy over the Industry Life Cycle* by Baum, J., McGahan, A. (eds.), Boston (MA): 1-21.

Mesenbourg, T. and Atrostic, B. (2001), "Measuring the U.S. Digital Economy: Theory and Practice," *U.S. Bureau of the Census*, Available on: http://isi.cbs.nl/iamamember/CD2 /pdf/1074.PDF, (Accessed on 30th May, 2007).

Microbanker, (2001), "*The Gap Between Large Banks And Small Widens on the Internet,*" White paper.

Microbanker, (2002), "*Internet Banking Systems Analysis,*" White paper.

Mobic (2001), "Gold Systems, Inc. Teams with Provident Wireless Web Access to Banking Customers". http://www.mobic.com/oldnews/2001/01/gold_systems.htm, (Accessed on 8th October, 2004).

Momma, A. (2000), "Value Delivery through Product-based Services," Unpublished Thesis, Master of Science in Management of Technology, Massachusetts Institute of Technology Library.

Mullahy, J. (1997), "Instrumental Variable Estimation of Count Data Models," *Review of Economics and Statistics*, 79(4): 586-593.

Muller, H., Jahnke, J., Smith, D., Storey, M-A., Tilley, S., and Wong, K. (2000), "Reverse Engineering: A Roadmap," Taken from "The Future of Software Engineering", Anthony Finkelstein (Ed.), ACM Press 2000, presented at ICSE --- Future of Software Engineering Track.

Nelson, R. and Winter, S. (1982), *An Evolutionary Theory of Economic Change*, Cambridge, Massachusetts: The Belknap Press of Harvard University Press.

Nobeoka, K. and Cusumano, M. (1997), "Multiproject Strategy and Sales Growth: The Benefits of Rapid Design Transfer in New Product Development," *Strategic Management Journal,* 18(3): 169-186.

Nonaka, I. (1994), "A Dynamic Theory of Organizational Knowledge Creation," *Organizational Science*, 5(1): 14-37.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, Oxford.

O'Brien, J. and Marakas, G. (2006), *Management Information Systems*, 7th International Edition, New York: McGraw-Hill.

OECD (1996), *The Knowledge-based Economy*, Paris: p7

Online Banking Report (1999), "True Web Banks and Credit Unions," Available on www.onlinebankingreport.com, (Accessed on 26th April, 2004).

PalmZone.net (2006), "PalmZone.net PDA Guide: Selection: All Models," Available on http://www.palmzone.net/pdaguide.php?rop=list&show=All_Models&search=palm, (Accessed on 20th Feb, 2006).

Parallel Graphics (2001), "Company Information: The History," Available on http://www.parallelgraphics.com/company/history/,' (Accessed on 3rd March, 2001).

Parry, M. and Bass, F. (1990), "When to Lead or Follow? It Depends," *Marketing Letters*, 1 (November): 187-198.

Patel, P. and Pavitt, K. (1997), "The Technological Competencies of the World's Largest Firms: Complex and Path-Dependent, But not Much Variety," *Research Policy,* 26: 141–156.

Pisano, G., Russo, M. and Teece, D. (1988), "Joint Ventures and Collaborative Arrangements in the Telecommunications Equipment Industry," In D. Mowery (ed.), *International Collaborative Ventures in U.S. Manufacturing*, Ballinger, Cambridge, MA, 23-70.

Pisano, G. (1990), "The R&D boundaries of the firm: an empirical analysis," *Administrative Science Quarterly*, 35: 153-176.

Powell, W., Koput, K. and Smith-Doerr, L. (1996), "Inter-Organizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly*, 41: 116-145.

Polanyi, M. (1958), *Personal Knowledge*. London: Routledge.

Prabhu, J., Chandy, R. and Ellis, M. (2005), "The Impact of Acquisitions on Innovation: Poison Pill, Placebo or Tonic?," *Journal of Marketing Research*, 69 (January): 114-130.

Prencipe, A. (1997), "Technological Competencies and Product's Evolutionary Dynamics: A Case Study from the Aero-Engine Industry," *Research Policy*, 25: 1261-1276.

Prencipe, A. (2000), "Breadth and Depth of Technological Capabilities in Complex Product Systems: The Case of the Aircraft Engine Control System," *Research Policy*, 29: 895-911.

Prencipe, A. (2001), "Exploiting and Nurturing In-house Technological Capabilities: Lessons From the Aerospace Industry," *International Journal of Innovation Management*, 5(3): 299-321.

Prencipe, A. and Tell, F. (2001), "Inter-Project Learning: Processes and Outcomes of Knowledge Codification in Project-Based Firms," *Research Policy*, 30: 1373-1394.

Prersson, I. (2002), "Essays on the Assumption of Proportional Hazards on Cox Regression," Dissertation for the Degree of Doctor of Philosophy in Statistics at Uppsala University.

Quah, D. (1996), *The Invisible Hand and the Weightless Economy*, Centre for Economic Performance Occasional Paper No.12, London School of Economics, London.

Quah, D. (1999), *The Weightless Economy in Economic Development*, Centre for Economic Performance Discussion Paper No.417, London School of Economics, London.

Roberts, P. and Amit, R. (2003), "The Dynamics of Innovative Activity and Competitive Advantage: The Case of Australian Retail Banking, 1981-1995," *Organization Science*, 14(2): 107-122.

Robinson, W. (1988)," Sources of Market Pioneer Advantages: The Case of Industrial Goods Industries," *Journal of Marketing Research*, 25 (February): 87-94.

Robinson, W. and Fornell, C. (1985), "Sources of Market Pioneer Advantages in Consumer Goods Industries," *Journal of Marketing Research*, 22 (August): 305-317.

Robinson, W., Kalyanaram and Urban, G. (1994), "First-Mover Advantages from Pioneering New Markets: A Survey of Empirical Evidence," *Review of Industrial Organization*, 9 (February): 1-23.

Rosenkopf, L. and Nerkar, A. (2001), "Beyond Local Search: Boundary-Spanning, Exploration, and Impact in the Optical Disk Industry, *Strategic Management Journal*, 22: 287-306.

Rothaermel, F. (2001), "Incumbent's Advantage Through Exploiting Complementary Assets Via Interfirm Cooperation," *Strategic Management Journal*, 22: 687-99.

Sahal, D. (1981), *Patterns of Technological Innovation*, Addison-Wesley, Reading, MA.

Santi, M. (2003), "Photography Mass Market: The Digital Issue (A: End of 1998)," ECCH Case 303-037-1, Groupe HEC-CCIP.

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

Schumpeter, J. (1950). *Capitalism, Socialism and Democracy*, Harper Brothers: New York

Shankar, Venkatesh, Gregory S. Carpenter, and Lakshman Krishnamurthi (1998), "Late Mover Advantage: How Innovative Late Entrants Outsell Pioneers," *Journal of Marketing Research*, 35 (February), 54–70.

Shawn, B. (2000), "The Jeff Hawkins Story," *Pen Computing Magazine* (50), Available on http://pencomputing.com/palm/Pen33/hawkins2.html, (Accessed on 20th Feb, 2006).

Smith, K., Collins, C. and Clark, K. (2005), "Existing Knowledge, Knowledge Creation Capability, and the Rate of New Product Introduction in High-Technology," *Academy of Management Journal*, 48(2): 346-357.

Sorescu, A., Chandy, R. and Prabhu, J. (2003), "Sources and Financial Consequences of Radical Innovation: Insights from Pharmaceuticals," *Journal of Marketing*, 67 (October): 82-102.

Spender, J. (1996), "Making Knowledge the Basis of a Dynamic Theory of the Firm," *Strategic Management Journal*, 17: 45-62.

Starita, L. (1999), "Online Banking: A Strategic Perspective," *Context Overview Report*, R-08-7031-Gartner.

Stock, J. and Watson, M. (2003), *Introduction to Econometrics*, Addison Wesley: Boston.

Szulanski, G. (1996), "Exploring Internal Stickiness: Impediments to the Transfer of Best Practice within the Firm," *Strategic Management Journal*, 17 (Special Issue: Winter): 27-43.

Teece, D. (1986). "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," *Research Policy*, 15: 785-805.

Teece, D. and Pisano, G. (1994), "The Dynamic Capabilities of Firms: An Introduction," *Industrial and Corporate Change*, 3(3): 537-556.

Teece, D., Pisano, G. and Shuen, A. (1997), "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, 18(7): 509-533.

Tegarden, L., Hatfield, D. and Echols, A. (1999), "Doomed from the Start: What is the Value of Selecting a Future Dominant Design?," *Strategic Management Journal*, 20: 495-518.

Tellis, G. and Golder, P. (1996), "First to Market, First to Fail?: Real Causes of Enduring Market Leadership," *Sloan Management Review*, Winter: 65-75.

Tellis, G. and Golder, P. (2001), *Will and Vision: How Latecomers Grow To Dominate Markets*, McGraw Hill.

Tripsas, M. (1997), "Unraveling the Process of Creative Destruction: Creative Assets and Incumbent Survival in the Typesetter Industry", *Strategic Management Journal*, 18 (Summer Special Edition): 119-142.

Tsai, W. (2001), "Knowledge Transfer in Intra-organizational Networks: Effects of Network Position and Absorptive Capacity on Business Unit Innovation and Performance," *Academy of Management Journal*, 44(5): 996-1004.

Tushman, M. and Anderson, P. (1986), "Technological Discontinuities and Organizational Environments", *Administrative Science Quarterly*, 31: 439-465.

Tushman, M. and O'Reilly III, C. (1996), "Ambidextrous Organizations: Managing Evolutionary Change and Revolutionary Change," *California Management Review*, 38(4): 8-30.

Urban, G., Carter, T., Gaskin, S., and Mucha, Z. (1986), "Market Share Rewards to Pioneering Brands: An Empirical Analysis and Strategic Implications," *Management Science*, 32 (June): 645-659.

U.S. Department of Commerce (2000), "Digital Economy," Available on http://www.stat-usa.gov/pub.nsf/4cfc4c4520d496ac852570430059bc91/fc9ea6b39fa8c3fe85257211006fc3bb/$FILE/dig2000.pdf, (Accessed on 30th May 2007).

Van den bosch, F., Volberda, H. and de Boer, M. (1999), "Coevolution of Firm Absorptive Capacity and Knowledge Environment: Organizational Forms and Combinative Capabilities," *Organization Science*, 10(5): 551-568.

von Hippel, E. (1994), "Sticky Information and the Locus of Problem Solving: Implications for Innovation," *Management Science*, 40(4): 429-439.

Wade, J. (1995), "Dynamics of Organizational Communities and Technological Bandwagons: An Empirical Investigation of Community Evolution in the Microprocessor Market," *Strategic Management Journal*, 16, (Summer Special Issue): 111–133.

Windmeijer, F. and Santos, J. (1997), "Endogeneity in Count Data Models," *Journal of Applied Econometrics*, 12: 281-294.

Wright, P. (1928), *The Tariff on Animal and Vegetable Oils*, New York: Macmillan.

Wuyts, S., Dutta, S. and Stremersch, S. (2004), "Portfolios of Interfirm Agreements in Technology-Intensive Markets: Consequences for Innovation and Profitability," *Journal of Marketing*, 68: 88-100.

Zahra, S. and George, G. (2002), "Absorptive Capacity: A Review, Reconceptualization, and Extension," *Academy of Management Review,* 27(2): 185-203.

Zander, U. and Kogut, B. (1995), "Knowledge and the Speed of the Transfer and Imitation of Organizational Capabilities: An Empirical Test," *Organization Science*, 6(1): 76-92.

Zollo, M. and Winter, S. (2002), "Deliberate Learning and Evolution of Dynamic Capabilities," *Organization Science*, 13 (3), May-June: 339-351.