Knowledge transfer through congenital learning: spin−out generation, growth and survival

Rajshree Agarwal
University of Illinois at Urbana−Champaign

Raj Echambadi
University of Central Florida

April M. Franco
The University of Iowa

MB Sarkar
University of Central Florida

Abstract

This paper examines the role of knowledge as a driver of an organization's formation, and as a subsequent source of its competitive advantage. We investigate the parent−progeny knowledge transfer relationship, and the impact of this congenital learning on the evolution and performance of a spin−out (an entrepreneurial venture by an ex−employee). Using data from the disk drive industry, we show that incumbent knowledge capabilities, related to technology and market pioneering, predict spin−out formation. Parent's capabilities at the time of spin−out founding positively affect spin−out knowledge capabilities, and result in spin−outs having higher probabilities of survival relative to other entrants.

All authors contributed equally. The names are arranged in alphabetical order

Published: 2002
URL: http://www.business.uiuc.edu/Working_Papers/papers/02−0101.pdf

Knowledge Transfer Through Congenital Learning: Spin-out Generation, Growth and Survival

Rajshree Agarwal
Dept. of Business Administration
University of Illinois at Urbana Champaign
350 Wohlers Hall, 1206 S. Sixth St.
Champaign, IL 61820
Email: agarwalr@uiuc.edu

Raj Echambadi
Dept. of Marketing
College of Business Administration
University of Central Florida
P.O. Box 161400
Orlando, Fl 32816-1400
Email: rechambadi@bus.ucf.edu

April M. Franco
Dept. of Economics
W210 John Pappajohn Business Building
The University of Iowa
Iowa City, IA 52242-1000
Email: afranco@blue.weeg.uiowa.edu

MB Sarkar
Dept. of Marketing
College of Business Administration
University of Central Florida
P.O. Box 161400
Orlando, Fl 32816-1400
Email: msarkar@bus.ucf.edu

All authors contributed equally. The names are arranged in alphabetical order

January 2002

The authors thank Dr. Bisakha Sen for her help with estimation issues. We appreciate the comments received from seminar participants at the University of Houston, University of Illinois at Urbana Champaign, University of Minnesota and Harvard Business School.

Knowledge Transfer Through Congenital Learning:
Spin-out Generation, Growth and Survival

ABSTRACT

This paper examines the role of knowledge as a driver of an organization's formation, and as a subsequent source of its competitive advantage. We investigate the parent-progeny knowledge transfer relationship, and the impact of this congenital learning on the evolution and performance of a spin-out (an entrepreneurial venture by an ex-employee). Using data from the disk drive industry, we show that incumbent knowledge capabilities, related to technology and market pioneering, predict spin-out formation. Parent's capabilities at the time of spin-out founding positively affect spin-out knowledge capabilities, and result in spin-outs having higher probabilities of survival relative to other entrants.

"No amount of legal protection can make a thoroughly appropriable commodity of something as intangible as information" (Kenneth Arrow, 1962)

The importance of knowledge in management research is reflected in contemporary research on organizational learning (Huber 1991; Levitt and March 1988), knowledge-based perspective within the resource-based view (Barney 1986; Miller and Shamsie, 1996; Grant 1996), and knowledge management (Nonaka 1994; Eisenhardt and Martin 2000). By viewing organizations as comprising of both knowledge-exchanging and knowledge-producing subsystems (Schulz 2001), two core themes that emerge from this literature relate to knowledge as the basis of a) organizational founding and b) organizational performance and survival.

The first stream relates to the sociological aspects of inter-organizational learning that takes place through congenital knowledge transfers that result when founders bring in critical knowledge from their employers to their embryonic organization (Huber, 1991). For example, a particular sociological perspective considers executive migration as a mode through which knowledge spillovers occur. In the special case when an employee leaves a firm to found an entrepreneurial venture, the transfer of rules, routines and procedures from parent to progeny organizations (Brittain and Freeman 1986; see Romanelli 1991) suggests that knowledge transfer across firm boundaries can lead to organizational speciation, which is a central focus in organizational ecology. The second stream investigates strategic perspectives relating knowledge-based capabilities to the search for competitive advantage (Eisenhardt and Martin 2000; Liebeskind, 1996; Spender, 1996). Little extant research, however, examines the link between these two processes.

For instance, while a theme in strategy research relates performance to the knowledge advantage brought about by privately held, tacit knowledge and the accumulation and manipulation of knowledge flows (Dierickx and Cool 1989;Eisenhardt and Martin 2000; Grant 1996; Teece, Pisano and Schuen 1997), there is little empirical evidence of the performance implications of congenital knowledge transfers (Huber 1991). It has been argued that organizations do not start with clean knowledge slates, and that "what an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters" (Huber 1991, p. 91). Very much like the reproduction and transmission of biological genes (Winter 1991), organizational blueprints consisting of unique insights and decision rules used to transform resources into action (Prahalad and Bettis 1986), cognitive dimensions of competency (Fiol 1991), specific knowledge and information (Boeker 1997), can all be transferred through founders from parents to progenies.

In addition, Stinchcombe (1965) observes that firms often emerge from other firms, and because they are set on a course at founding, their learning, capability accumulation, and performance all become inextricably linked to their inherited knowledge. Starting with a 'good model' (Ingram and Baum 1997) can result in sustained inter-firm variance in performance (Cyert, Kumar and Williams 1993). Thus, the initial stock of knowledge resources that are transferred through congenital learning can become a source of a sustainable competitive advantage. Together, these perspectives suggest that a compelling avenue of research on knowledge would merge the disparate streams of literature in order to examine the effect of inter-firm knowledge transfer on organizational founding, and their subsequent performance.

In this article, we first focus on knowledge as a driver of organization formation. We investigate how an incumbent's knowledge affects its likelihood of generating progeny organizations, which we term as spin-outs. Spin-outs are defined as an entrepreneurial venture founded by an employee of an incumbent firm within one year of leaving the incumbent and which competes in the same industry as the parent[1]. Innovation is often the impetus behind their formation, and knowledge-rich research engineers with support of venture capitalists typically

[1] Although systematic empirical studies on high technology start-ups are few, the terminology related to this organizational form is often confusing. The term 'spin-offs' has been used to refer to new firms that result from employee entrepreneurship (Klepper and Sleeper 2000; Dahlstrand 1997) and those that result from corporate restructuring (Allen 2001). To mitigate this confusion, we use the term "spin-out" which has been coined and used in popular magazines (e.g. *Business Week*). Thus, as opposed to "spin-offs" or ventures by incumbent firms that are *intentionally* created, we focus on spin-outs and the *unintentional* transfer of knowledge and creation of potential competition.

found spin-outs. We then specifically address the issue of congenital knowledge and examine its effects on knowledge trajectories over time.

In spite of spin-outs representing a particularly important agent of market evolution (Garvin 1983), our understanding of spin-outs is limited. Although various factors such as human capital, stage of the industry cycle (Garvin 1983), an employee's job prospects in their current position, and firm know-how (Brittain and Freeman 1986) have been related to spin-out formation, there is a void in our understanding of how 'basically new forms of organizations' are created (Singh and Lumsden 1991). Despite the prominence of spin-outs in industries such as semiconductors (Braun and Macdonald 1978; Malone 1985), disk drives (Chesbrough 1999; Christensen 1993), and more recently in information technology firms (Propson 2000), we know little about the types of firms that spawn them (Klepper and Sleeper 2000). Secondly, although Phillips (2000) relates the failure rates to the parent-progeny relationship among law firms, there has been little systematic investigation of the congenital knowledge transfers from parent firms to their off-spring relating to technological and marketing capabilities. Given that much of the know-how may be tacit implies that they are difficult to transfer or imitate (Conner and Prahalad 1996). Important questions also arise regarding the sustainability, over the life cycle of a spin-out, of knowledge advantages at the time of founding made possible through congenital learning.

In undertaking this inquiry, we argue that it is a combination of inside-out and outside-in knowledge-based capabilities that lead to competitive advantage (Day 1994; Moorman and Slotegraaf 1999). While inside-out capabilities relate to technological know-how, outside-in capabilities relate to an organization's ability to undertake advantage of market making opportunities. We relate these two capabilities to the main themes in this paper, namely an inquiry into the phenomena surrounding the birth of spin-outs, the process of their growth, and survival.

THEORETICAL FRAMEWORK

We organize the theoretical framework along three themes. Although we account for alternate explanations where appropriate, our primary focus on knowledge-based capabilities is driven by a strategic, resource-based view of the firm. In high technology industries, new ventures are frequently established to bring new technologies into the market. As has been recognized by entrepreneurship researchers (Doutriaux 1992; Schoonhaven, Eisenhardt and Lyman 1990;), proprietary technical knowledge and marketing expertise are crucial capabilities for new ventures since they allow these new ventures to differentiate themselves, identify market opportunities, and commercialize their technology. Accordingly, we focus on these two critical knowledge based capabilities – namely technology and market making. These are used a proxies for the organizational capital that is embodied in the firm and provides it with a source of a sustainable competitive advantage.

In theme 1, we investigate the phenomena of spin-out formation and link parent traits to the incidence of spin-out formation. Theme 2 explores the issue of congenital knowledge transfer, and discusses the link between parental knowledge at the time of spin-out founding and the progeny's capabilities over time. Further, we argue that the parent-progeny knowledge transfer results in higher levels of knowledge-based capabilities of spin-outs relative to other entrants. In theme 3, we examine a performance outcome of interest to scholars in organizational ecology and technology management – namely firm mortality. Based on their congenital learning, we predict that spin-outs are likely to enjoy a survival advantage over other entrants.

THEME 1: Parental Knowledge and Spin-Out Generation

Technological Know-How In technology markets, the extent of scientific know-how embodied in a product is typically very high (John, Weiss, and Dutta 1999). Research creates R&D capital that has the potential to earn monopoly rents for a firm, while also increasing the human capital of research workers. R&D that leads to scientific know-how is perfectly codifiable and protectable by intellectual rights instruments, e.g. patents, and creates pure knowledge capital for the firm (Moen 2000). Typically, however, much of scientific knowledge is tacit, and substantive portions of a firm's R&D capital may be embodied in their employees. This intellectual human capital (Zucker, Darby and Brewer 1998), is transferable from one firm to another through labor mobility (Arrow 1962), or executive migration (Aldrich and Pfeffer 1976).

Employee access to valuable information and scientific know-how through working on research projects is likely to be higher if their employer is operating close to the technological frontier. Thus, employees at firms that are on the cutting edge of scientific know-how are also likely to possess higher levels of intellectual human capital compared to their counterparts at less technically advanced firms. Higher levels of potential know-how are likely to reduce entry barriers and generate greater entrepreneurial incentives since the perceived risk involved in giving up a secure job and launching into entrepreneurship is likely to be mitigated by the belief that one possesses valuable, and difficult to acquire know-how (Shaver and Scott, 1991). In addition, external financial institutions, e.g. venture capitalists, are likely to make direct associations between the parent's R&D capital and the intellectual human capital of the founder (Fried and Hisrich, 1994), and be more willing to back ventures where the transferable knowledge is more advanced. Further, employees with higher levels of scientific know-how are likely to face a larger opportunity set of exploitable market prospects through product differentiation and product unbundling. Accordingly, firms that are on the cutting edge of technology are also more likely to be fertile breeding grounds for entrepreneurial ventures. Thus,

H_1: The likelihood of spin-out generation will be increasing in an incumbent's technological know-how.

Market Pioneering Know-How Technological progress is generally characterized by long periods of incremental innovation punctuated by periods of radical change brought about by disruptive innovations (Abernathy and Utterback 1978, Tushman and Anderson 1986). Incremental innovations are typically trajectory sustaining, and are adopted relatively easily by incumbents since they not only draw on existing knowledge bases, but also are consistent with the demands of existing customers (Christensen 1993). On the other hand, disruptive innovations introduce a different package of attributes from what mainstream customers historically value, and often perform far worse than the current technology on dimensions that are important to these customers. These disruptive innovations often lead to changes in technological paradigms (Dosi 1982) and result in new technical sub-fields or new product-markets in an industry.

The early mover advantage literature suggests that market pioneering is a valuable organizational capability (Golder and Tellis 1993; Lieberman and Montgomery 1989; Robinson and Fornell 1985). Taking a technology to the market *early* is difficult, thus prompting researchers to suggest that early entry involves complex marketing skills that are qualitatively different from those required for late entrants (Bowman and Gatignon 1995; Kalyanaram, Robinson, and Urban 1995). In other words, the ability of a firm to commercialize disruptive technology ahead of competitors is a rare and valuable marketing capability.

It has been noted that marketing capabilities are both cultural and process-based in nature (Kohli and Jaworski 1990). Market orientation, which consists of planning and cross-functional decision making activities, represents superior skills in understanding and satisfying customers (Jaworski and Kohli 1993); marketing capabilities may be viewed as innovative behavior reflected in a firm's ability and will to be market driven (Narver and Slater 1990; Slater 1997).

The organizational memory literature suggests that market-pioneering know-how exists ubiquitously among members of an organization in the form of shared beliefs, values, norms, and behaviors (Argyris and Schon 1978; Deshpande and Webster 1989; Levitt and March 1988). Even without direct access to marketing operations, employees in market-driven firms are more likely to imbibe an external market-focused world-view. In fact, employees may not only internalize lessons from the organization's prior experiences in market pioneering, but also imbibe its belief structure, behavioral routines, and procedural and declarative knowledge on new product development and marketing (Moorman and Miner 1997). 'War stories' and 'hall talk' of past market pioneering successes are likely to motivate a potential founder to embark on one's own and reap entrepreneurial rents. Accordingly, market pioneering could positively influence an employee's propensity to leave and form an entrepreneurial venture.

We note that an alternative line of reasoning to the above facilitating effect of market pioneering capabilities on spin-out generation could be that an incumbent could *deter* spin-out formation through a sustained strategy of aggressive entry into emerging technological sub-fields. By moving early to occupy an emerging technological sub-field, an incumbent organization could preempt market niches. However, in balance, we believe that the facilitating effect of market pioneering know-how on spin-out formation is likely to prevail under most circumstances for the following reason. In high-technology markets, which are characterized by comparatively high amounts of embodied scientific know-how in their products compared to other assets, product unbundling encourages both the amount and diversity of new technology introduction (John, Weiss, and Dutta 1999). This increases the opportunity set of exploitable market prospects that are available to innovative entrants (Kessides 1991), and allows more than one firm to prosper. Employees enthused with entrepreneurial fervor and wanting to appropriate a larger portion of the economic value of their scientific know-how are likely to find market niches regardless of parent presence. Thus, we posit that:

> *H_2: The likelihood of spin-out generation will be increasing in an incumbent's market pioneering know-how.*

Interaction of Technological Know-How and Market Pioneering Know-How In addition to their direct and positive effects, we believe that an incumbent's technology and market-pioneering know-how will interact so as to *reduce* the chances of spin-out formation. Due to the human embodiment of an organization's technological and market pioneering know-how, employees are likely to be empowered to venture out carrying with them cutting-edge product development knowledge or marketing savvy. However, when an incumbent possesses high levels of both capabilities, the incidence of spin-out formation is likely to be lowered.

It has been noted that the ability of a firm to profit from technological innovation depends on the simultaneous presence of two co-specialized assets, namely product technology and market pioneering capabilities (Moorman and Slotegraaf 1999; Teece 1986). While firms need a certain level of technological capability to maximize the value of market opportunities (Bierly and Chakrabarti 1996; Cohen and Levinthal 1990), they also need marketing know-how to appropriate the potential stream of economic rents that lie embodied in their technological breakthroughs (Dierickx and Cool 1989; Teece 1988). Their complementary nature creates a valuable synergy (Day 1994) that increases a firm's effectiveness and efficiency (Park and

Zaltman 1987; Walker and Ruekert 1987). Moreover, firms exhibiting these complementarities are likely to inhibit competitive imitation due to the inherent difficulty of developing these two capabilities simultaneously (Grant 1991; Lippman and Rumelt 1982; Reed and DeFillippi 1990).

We argue that the co-presence of both technological and marketing capabilities in an organization will reduce chances of spin-out formation. First, incumbents with high levels of both technological and market pioneering know-how are likely to reduce the incentives for employees to embark out. Such organizations diminish scientists' and engineers' sense of aggravation in not seeing their inventions find market place expression, as opposed to an organization that has high technological capabilities but lacks market pioneering know-how (Christensen 1993, 1997; Garvin 1983). Thus, higher levels of job satisfaction and perceived brighter prospects when the organization is committed to taking emergent technological developments to market may reduce chances of employee mobility (Benkhoff 1997). Second, incumbent organizations that possess high-end technological capabilities *and* are committed to going to the market with them exhibit a 'willingness to cannibalize' and are likely to sustain leadership in dynamic markets (Chandy and Tellis 1998). Correspondingly,

> *H_3: The greater the level of both technological know-how and market pioneering know-how in an incumbent, the lesser is the likelihood of spin-out generation.*

THEME 2: Congenital Knowledge and Spin-Out Characteristics

The organizational learning and knowledge spillovers literature together indicate yet another potent effect of a parent firm's knowledge base that goes beyond mere progeny generation and explains sustained heterogeneity in knowledge based capabilities both *among* spin-outs, and *between* spin-outs and other entrants. First, there occurs an inter-organizational transfer of know-how from parent to progeny through an employee who leaves to found an entrepreneurial venture. Since the quality, or level, of congenital knowledge is related to the spin-out's parent's stock of knowledge at the time of its creation, a spin-out's relative technological and market pioneering know-how are determined by parental knowledge. In conjunction with the absorptive capacity argument, this implies that the initial stock of know-how leaves a lasting imprint on a new firm's trajectory, and leads to "smart" parents creating "smart" off-springs. In other words, parental knowledge impacts a spin-out's knowledge accumulation over time. Accordingly, spin-outs founded from knowledgeable parents are themselves likely to enjoy persistently elevated levels of know-how levels compared to spin-outs with less knowledge intensive parents. Second, we argue that the congenital knowledge inherited from parents constitutes a sustainable source of knowledge based competitive advantage, since it enables spin-outs to maintain a 'knowledge edge' over other market entrants.

Research suggests that employee mobility facilitates the transfer of knowledge and competencies across organizations (Aldrich and Pfeffer 1976; Franco and Filson 2000). Scientific knowledge is diffused across organizations and into a larger institutional context through executive migration (Arrow 1962; Boeker 1997; Moen 2000). R&D spillovers occur when researchers, paid by a firm to generate new knowledge, transfer to another firm or form a spin-out. Similarly, marketing related managerial capabilities may also migrate along with personnel movements. Boeker (1997) illustrates how corporate level strategic choices, as reflected in product-market entry decisions, are influenced by executive migration and by the unique set of skills and perspectives that top managers bring in from their prior organizations.

Therefore, in contrast to physical assets, human capital is under limited organizational control, and thus associated with information problems due to the threat of voluntary turnover (Coff 1997). Further, when innovations cannot be properly codified or protected by patents, a firm's R&D capital is largely embodied in its employees in the form of intellectual human capital (Zucker, Darby and Brewer 1998). In fact, Stinchcombe and Heimer (1988) have described such firms as 'precarious monopolies,' since key experts may depart with the focal firm's knowledge. Research workers not only sell the services of their skills, but also simultaneously purchase an opportunity to augment those skills (Rosen 1972), and thus appropriate part of the economic rents associated with knowledge created during tenure at the employer organization. In essence, spillovers imply that a separate, and different organization exploits the exploratory knowledge of a firm, and in this context, a spin-out transfers and commercially exploits the results of R&D activities of the parent firm. In fact, as Teece (1988) argues, a complex part of technology transfer relates to its "softer" side which goes beyond information codified in scientific papers, formulae, technical specification, blueprints and hardware, and is held in the form of tacit, non-articulable "knowledge and competence assets" (Zander 1991) by individuals (Badaracco 1991; Kogut and Zander 1992).

These spillovers in R&D and marketing know-how from the parent firm constitute a critical component of what has been termed as an organization's congenital knowledge, or the "combination of the knowledge inherited at its conception and the additional knowledge acquired prior to its birth" (Huber 1991, p. 91). A spin-out thus imbibes its congenital knowledge from the parent's stock of knowledge through its founder. The initial stock of knowledge is a vital component of a start-up's initial stock of resources that serves as the foundation on which it creates new knowledge. Given the important influence of founding conditions on an organization's evolution (Stinchcombe 1965), this initial stock of knowledge is likely to influence a spin-out's future flow of knowledge-based capabilities over time since prior information creates a "knowledge corridor" that triggers discovery (Shane 2000; Venkataraman 1997) and "congenital knowledge strongly influences future learning" (Huber 1991, p. 91).

Further, the notion of absorptive capacities provides the link between a firm's congenital knowledge and its trajectory of capability accumulation over time. A firm's ability to learn over time depends on its level of prior related knowledge. According to Cohen and Levinthal (1990), this initial stock of knowledge relating to most recent scientific or technological developments in a field confers higher absorptive capacity on a firm. This is defined as the firm's ability to recognize the value of new information, assimilate it, and apply it. The learning process whereby firms accumulate technological capital is a function of absorptive capacity, and related to its initial stock of knowledge. Path dependency in the accumulation of technological capabilities occurs through the facilitation by prior scientific and technological knowledge of the understanding and generation of new knowledge. It results in the stock of knowledge at founding leaving a long-lasting imprint on a firm's future competitiveness. Accordingly, there is a *within group variance* among spin-out firms' capability accumulation which depends on the initial stock of know-how that it inherits from its parent. The related hypothesis is then,

> *$H_{4a\text{-}b}$: The trajectory of a spin-out's (a) technological know-how and (b) market pioneering know-how will be increasing in its parent's technological know-how and market pioneering know-how at the time of the spin-out's inception, respectively.*

Further, the above line of reasoning also suggests an *across group variance* and that spin-outs are likely to have a knowledge creation advantage over other entrants. Simply put, spin-outs have a *start-up* congenital knowledge advantage that enables them to *sustain* knowledge leadership over non spin-out entrants. During the initial time interval between when an organization is first conceived of and its formal founding, founders of spin-out and non spin-out firms alike typically employ a combination of vicarious learning, grafting and searching to enhance the congenital knowledge base of the organization-to-be (Huber 1991). Possibly, this deliberate process of knowledge acquisition partially distinguishes the richness of knowledge transferred through founders who are entrepreneurial ex-employees of incumbent firms from knowledge acquired by non spin-out entrants that have the option of hiring away employees from incumbent firms. The directness of the congenital knowledge inherited by spin-outs makes them better off at founding than non-spin-outs. Starting off with a higher initial stock of knowledge implies that spin-outs have the potential to sustain their technological leadership relative to other entrants through R&D innovation. Due to higher levels of absorptive capacity at each period, spin-outs can learn and take advantage of technological know-how that is generated both internally and externally. Thus, compared to non spin-out start-ups, spin-outs are likely to be advantaged in the learning race that typifies most high technology industries. Thus,

> *$H_{5a\text{-}b}$: Spin-outs will enjoy a higher trajectory of (a) technology know-how, and (b) market pioneering relative to other entrants.*

THEME 3: Spin-out Survival

We now turn to a crucial question related to performance, namely that of organizational mortality, and investigate whether there are likely to be systematic differences in survival between spin-out and non-spin-out entrant firms. In high technology markets, characterized by rapid changes and progressing frontiers, a firm that falls behind in technological capabilities risks not being able to survive to the following period. Earlier, we argued that transfer of know-how, rules and routines from a technologically advanced parent gives spin-outs a head start. This allows spin-outs not only to start at a higher point on the learning curve compared to other entrants, but also to sustain this advantage over time.

In addition to the advantages of superior technological and market pioneering capabilities, spin-outs are likely to be privileged in other ways as well. Having imbibed the experiential learning of their parents with regard to reliable routines, spin-outs have the advantage of 'inside' knowledge and are less likely to face the costs of a pure trial and error process relative to other entrants. Further, institutional theory suggests that spin-outs also inherit social capital, such as reputation and connections into the parent's network (Higgins and Gulati 1999). This results in more legitimization with external stakeholders. Previously established connections and valuable internal routines possibly reduce spin-outs' liabilities of newness (Stinchcombe 1965) and adolescence (Levinthal and Fichman 1988) compared to other entrants.

In combination with tacit knowledge advantages and social capital inheritance that clearly benefits spin-outs, an additional source of advantage to spin-outs may stem from their entrepreneurial origin. Entrepreneurship literature argues that 'venture origin' is an important source of resource differences, strategies and performance of new firms (Knight 1989; Lambkin 1988; Shrader and Simon 1997). Greater motivation, and autonomy may lead to differences in the ways resources are combined and utilized by entrepreneurial spin-outs as compared to entrants with parental backing (Knight 1989). Therefore, in combination with capability advantages stemming from congenital knowledge transfers, entrepreneurial value creation is likely to advantage spin-outs over other forms of entrants. Accordingly, we argue that

> *H_6: The likelihood of survival for spin-out entrants will be greater than for non spin-out entrants.*

METHOD

Data and Measurement

Description of Data We test our hypotheses using data collected from the rigid disk drive industry. Disk drives are magnetic information storage devices used with computers. IBM introduced the first completely sealed and removable disk drive, the 14-inch Winchester in 1973. Fueled by the growth in personal computers, the disk drive industry was been characterized by a great deal of innovative activity, with numerous architectural, modular and incremental innovations[2] (Henderson and Clark 1990) being observed in the 20-year period that we consider. Architectural innovations resulted in five new diameters that catered to newer markets being introduced after the initial introduction of the 14" drive. Also, several modular and incremental innovations resulted in dramatic increases in the storage capacities of the disk drives. We refer interested readers to Christensen (1993, 1997) for detailed histories of the rigid disk drive. In response to profit opportunities from such rapid technological dynamism and market growth, net entry occurred, and both spin-out and non spin-out entry peaked shortly before the industry shake-out in 1986. Among the entering firms, approximately 25% of firms were spin-outs and they represent an important source of knowledge diffusion and technology transfer in this industry[3]. Thus, the richness of the events and the availability of spin-outs data make the disk-drive industry an appropriate industry for our analysis.

---

[2] Optical drives are considered radical innovations, but are not included in the dataset since their introduction date occurred late in the time period under study and there are not enough longitudinal data on the firms producing optical drives.

[3] The legal environment within the disk drive industry, not atypical for most high tech industries, did not create significant hurdles for employee mobility causes of technology transfer. First off, most of the disk drive manufacturers are in California, which does not enforce non-competing clauses in labor contracts. Further, the trade secret laws that do exist have not been particularly useful either in preventing employee mobility and spin-out generation. As noted by Lerner (1997), there is a general reluctance to patent disk drive technologies due to the rapid pace of technology improvements that limits the usefulness of the patents given the time needed to acquire them. In particular, only two of the 198 U.S. patents awarded from 1971 to 1988 that covered disk drive technologies had a primary assignment in or cross-reference to disk drive storage density, the focus of this study. Further, no litigation that occurred involved drive density. The phenomena of high employee mobility is similarly observed in the semiconductor

One of the main problems with testing hypotheses related to spin-out generation and firm survival is the lack of historical data. For accuracy, particularly on the early histories of firms in the disk drive industry, we collected data from sources that document facts *at the time of occurrence,* rather than rely on recollections of events. Creating such a database entailed using a reliable data source that would track information on important historical events in the industry and for *all* firms and that entered and exited these specific new markets. We use information compiled from the *Disk/Trend Report,* a market research publication that has covered the disk drive industry since 1977. It is a reliable and complete data source that has been used in past studies (Christensen 1993, 1997; Christensen and Bower 1996; Christensen, Suarez, and Utterback 1998; Lerner 1997). We constructed the genealogy of the firms and determined parent-progeny relationships based on background information of founders of new firms from the *Disk/Trend Report,* supplemented by additional company press reports and news releases, and other data sources including various technological sources, scientific journals, books, articles in periodicals, chronologies, and directories (e.g. the *Directory of Corporate Affiliations*, and the *International Directory of Company Histories.*). The information search and data collection tasks were time and effort intensive. To minimize possible data-entry errors, the database was developed independently by three research assistants. The databases were then compared to reconcile discrepancies, rectify mistakes, and ensure that the records were accurate. The entire exercise was overseen by two researchers with intimate knowledge and record of academic publication in related research areas.

The final database contains the entire census of firms in the industry during the 1977-1997 period. In addition to the 39 incumbents that entered between 1973 and 1976, there were 153 new entrants, of which 40 were spin-outs. Since every productive firm, regardless of size, is included for their span of existence in the market, our sample does not suffer from survival bias for the period under analysis. The panel database consists of 1190 firm/year observations and

---

and software industries; rather than use of patents, Bell Labs conducted seminars to teach their competition about how to make integrated circuits, which were the precursor to semiconductors.

includes detailed information on introduction dates of the new diameters in the industry, product characteristics, and annual sales of disk drives[4].

Operationalization of Constructs Table 1 provides the rationale and empirical operationalization of all the variables used in the study. The descriptive statistics and correlation matrix are presented in Table 2. The operationalization of two key variables namely, market pioneering and technological know-how are described below.

[Insert Table 1 here]

[Insert Table 2 here]

Market Pioneering Know-how: All the major architectural innovations in this industry catered to and satisfied new markets. Five such innovations, namely the 8", 5.25", 3.75", 2.5", and 1.8" drives, were introduced between 1977-1997. The market pioneering know-how variable captures the know-how associated with bringing an innovation to market. We operationalize this variable as the number of times a firm introduced a drive of a new diameter within the first year of the diameter's introduction into the market as a proportion of the total number of opportunities available to the firm for doing so[5]. Since there were five distinct diameters introduced in the period under study, the market pioneering know-how of a firm varies over time and across firms.

Average Relative Technological Know-how: The outcomes of all modular and incremental innovations are manifested in 'areal density,' or the megabytes per square inch of a particular drive. Areal density, which measures how much information can be stored on each square inch of disk, is an important measure of product performance which enables cross-diameter comparisons. Figure 1 shows the rapid technological progress over the years within and across the diameters. The Hi-areal curve represents the highest areal density across all drives produced

---

[4] Sales information is available by firm at an aggregate disk-drive level, and not at the individual diameter level.

[5] While this operationalization is the most intuitively appealing, we experimented with alternative measures that included the absolute number of times a firm could be considered an early mover, and the negative of the number and proportion of missed market opportunities. All operationalizations yielded similar results.

in a particular year. Note that both 14 and 8 inch diameters experienced a withdrawal during this period. The dominance of newer diameters over time is evident by the fact that the highest areal density of the 14 inch drive is overshadowed by areal densities of 5.25 inch drives in 1987, which is subsequently overtaken by the 3.5 inch in 1988 and the 2.5 inch in 1997.

[Insert Figure 1 here]

We conceptualize a firm's technological capabilities as being reflected in its proximity to the technological frontier in each diameter at a point of time. Thus, our focus is on technological capabilities of a firm relative to the 'best' drive in the market. We calculate a firm's relative areal density in a particular diameter as follows. We first divide the areal density of the best drive produced by a firm in a given diameter in a particular year by the highest areal density in that diameter available in the market that year to obtain the firm's diameter specific relative technological position. We then average this measure across all diameters produced by the firm to obtain a measure of the firm's average relative technological know-how in a particular year[6]. This operationalization of a firm's technological capabilities circumvents issues relating to cumulative and absolute increases in technological know-how over time, since it is a *relative* measure that is calculated at each point in time.

Estimation Methodology

Several estimation techniques are used to test the hypotheses developed in the theoretical section, and are described below.

Theme 1: Spin-out Formation We use the family of count data models to test the hypotheses (H_1-H_3) pertaining to Theme 1. The probability of generating a spin-out is given by:

(1) $Pr(y_j) = f(Xi)$

[6] Note that we focus on the *average* relative technological know-how across all drives rather than the relative position of the firm in its best drive because a firm typically competes in more than one diameter with the other firms in the market, and we are interested in capturing its technological know-how across its product lines. This gives us a conservative estimate of technological know-how since a firm that continues to produce only in the older diameters will benefit from other firms dropping out the diameters that are leveling off and producing in markets that are advancing their technological frontier more quickly.

where y_i represents the number of spin-outs generated by firm "i" and X_i is the vector of firm attributes. The discrete probability function is commonly specified as a Poisson process, which models the expected number of spin-outs as

(2) $$\lambda_i = e^{Xb}$$

where X and b are the vectors of firm attributes and coefficients respectively. The Poisson process restricts mean and variance to be equal, and the negative binomial model extends the Poisson model by allowing the variance of the process to differ from the mean[7]. However, an over-dispersion of zero occurrences of spin-out generations may render both the Poisson and the negative binomial regression model inappropriate. Greene (1993) modifies the variance structure to account for this excess-zero problem in the following manner:

(3) $$var\ (y_i) = \lambda_i\ (1 - q_i)\ (\ 1 + \lambda_i\ q_i\ ),$$

where λ_i is the mean of the Poisson process and q_i is the probability of obtaining a structural zero which is a choice of not generating a spin-out[8]. When q_i approaches zero, the variance collapses into a Poisson process. This model allows for "excess zeros" in count data models under the assumption that the population is characterized by two regimes, one where members always have zero counts, and one where members have zero or positive counts[9]. The likelihood of being in either regime is estimated using a logit specification, while the counts in the second regime are estimated using a negative binomial specification. The Vuong statistic is used to test the appropriateness of the zero-inflated versions against the Poisson and negative binomial models.

[7] The negative binomial also loosens the deterministic specification of Poisson by including, in the parameter λ, a stochastic term that follows a gamma distribution, (var $(y_i/x_i) = \phi_i\ (1 + \delta\phi_i\ )$), such that the negative binomial collapses to a poisson as δ approaches zero.

[8] The negative binomial version includes a standard form of gamma heterogeneity in the poisson portion of the model. Such a specification implies that var $(y_i) = \lambda_i\ (1 - q_i)\ [1 + \lambda_i\ (q_i + \delta\ )]$.

[9] In order to discriminate between the two kinds of zeroes—the absence of spin-outs due to lack of opportunities or due to missed chances—we included market opportunities available as an important explanatory variable in the first estimation stage. New market opportunities in the industry facilitating entry (by spin-out and non spin-out firms alike) correspond to the introduction of the new diameters.

Theme 2: Congenital Knowledge and Spin-out Characteristics The hypotheses pertaining to spin-out learning from their parents ($H_{4a\text{-}b}$) are tested by restricting the sample to spin-out firm-year observations. We test the hypotheses $H_{5a\text{-}b}$ for differences between spin-out and non spin-out entrant characteristics by restricting the sample to post 1977 entrants. Seemingly unrelated regressions are used to estimate these hypotheses to account for potential correlations of the errors across the technological and market pioneering know-how equations.

Theme 3: Spin-out Performance

In theme 3, hazard rate analysis is used to test the hypothesis H_6 pertaining to survival as a performance measure. A firm's hazard rate, h(t) is defined as the probability that it will die in a particular time interval (t+ *Δt)*, given that it has survived until t. i.e. ,

(4) $$h(t) = \lim_{\Delta t \to 0} [Pr\,(t, t+\Delta \mid t\,] / \Delta t$$

This gives the probability of failure conditional on age. We modeled the firm's hazard rate $h_f(t)$ as a function of the explanatory variables as follows:

(5) $$h_i(t) = h(t; x_i) = \exp(x'i(t)\beta)$$

x_i and β are the vectors of explanatory variables for the i^{th} firm and regression parameters to be estimated respectively. Several discrete and continuous time analyses are available for the estimation of equation (5) (Allison 1995). Consistent with earlier studies (Baum & Oliver, 1991; Henderson, 1999), we used a multiple spells formulation with a complementary log-log specification that allows for time varying covariates[10]. To ensure robustness of the results, we estimated additional model specifications, which included probit, logistic, and Cox proportional hazards models. The results are very similar across the different model specifications.

[10] Although a firm may fail at any point within a given year, the data on failure are updated only annually. A multiple spells, complementary log-log formulation allows continuous-time hazard rates to be obtained from discrete time failure data. The instantaneous probability of failure of a firm at time t in this model is given by $h(t) = 1 - \exp[-\exp(\beta x_t)]$. See Allison (1995).

RESULTS

Theme 1: Spin-out Generation

The hypotheses generated in Theme 1 pertain to the knowledge capabilities of firms and the likelihood of spin-out generation. Accordingly, the observations pertain to firms being potential parents in every year after their entry, or after 1976 in the case of firms that entered prior to 1976[11]. The results of the tests of hypotheses 1-3 are shown in Table 3. Recall that H_3 proposes a contingent relationship. Since the evaluation of main effects change in the presence of an interaction term (Aiken and West, 1991), we estimate the model in two stages. In the first stage, the main effects and the control variables are entered. Models 3a and 3b report the negative binomial and zero inflated negative binomial regression results on the main effects of average relative technological know-how and market pioneering know-how. In the second stage, we enter and estimate the interaction between technological know-how and market pioneering know-how, and these results are presented in Model 3c (negative binomial) and Model 3d (zero inflated negative binomial). The Vuong statistic indicates that the negative binomial model is preferred to the zero inflated negative binomial for the main effects model, and vice versa for the interaction model. Either model, however, yields remarkably similar results[12].

[Insert Table 3 here]

Results from the main effects only models reveal that the probability of generating a spin-out in the following period increases with increases in both technological know-how and market pioneering know-how of the firm thereby supporting both H_1 and H_2. Among the firm specific control variables, age of the firm does not affect the likelihood of spin-out generation, however firms with higher sales are more likely to generate spin-outs. A firm with higher than the

[11] Since there was only one foreign firm that generated a spin-out, we do not include the foreign firm variable in the spin-generation hypotheses testing. Further, spin-outs that were generated prior to 1976 are not included in the analysis, since the panel data are available only after 1977, even though IBM and other firms generated several prior to 1977.
[12] The estimation results are also robust to using Poisson, zero inflated Poisson, probit and ordered probit model specifications.

average level of product diversity is less likely to generate a spin-out. The only industry level control variables that are significant relate to the linear and quadratic terms of competitive density. Examining the contingency model (Models 3c and 3d) shows that the interaction between technological know-how and market pioneering know-how negatively impacts the probability of generating a spin-out, thereby supporting H_3. Thus, our empirical results show strong support for each of the three hypotheses developed in Theme 1.

Theme 2: Congenital Knowledge and Spin-out Characteristics

Table 4 presents the results of the hypothesis pertaining to knowledge capabilities of spin-outs using seemingly unrelated regressions. The sample is restricted to observations pertaining to firms that are spin-outs. Results from Model 4a show that parent technological know-how measured in the year preceding spin-out entry is strongly significant in predicting spin-out's technological knowledge over time, thereby supporting H_{4a}. Similarly, Model 4b shows that parent market pioneering know-how measured in the year preceding spin-out entry is positive and significant in explaining spin-out market pioneering know-how over time[13], thereby confirming support for $H_{4b.}$ Among the control variables, age is significant for both equations, though it is seen to first decrease and then increase spin-out technological know-how, and it has the opposite effect on market pioneering know-how. Firm sales are positively related to spin-out market pioneering know-how, but not for technological know-how. Among the industry control variables, only industry sales matters in Model 4b, indicating that higher industry sales result in lower levels of market pioneering know-how of spin-outs.

[Insert Table 4 about here]

In Table 5, we report the results for hypotheses H_{5a-b} by considering all post-1977 entrants in the industry. Models 5a and 5b report the estimates from seemingly unrelated regressions for entrant technological know-how and market pioneering know-how respectively. In both models, the spin-out variable is significant and positive, thereby supporting H_{5a} and H_{5b}.

[13] The estimation results are robust to alternative model specifications including ordinary least squares and random effects panel regression.

Age has an inverted U-shaped relationship with market pioneering know-how. The impact of industry sales is negative on both technological know-how and market pioneering know-how. All other control variables do not matter in determining the technological know-how and market pioneering know-how of firms.

Theme 3: Spin-out Performance

Table 6 reports the results from the hazard rate analysis using the complementary log-log specification. The results from Model 6 reveal that spin-outs indeed have a higher probability of survival in a given year than non-spin-outs, thereby providing support for H_6. Higher technological know-how also increases the probability of survival, but market pioneering know-how is not seen to affect the probability of survival. A foreign firm has a higher probability of survival[14]. As would be expected, firm sales increases the probability of survival. The level of industry sales seems to affect survival adversely, but the growth of industry sales proves beneficial to the probability of survival. The number of firms competing in the market is significant and the signs on the quadratic specification are consistent with the organizational ecology literature. Further, survival also seems to be aided by increases in industry level technological knowledge.[15] Interestingly, parent presence in the same diameter is not seen to have an adverse effect on spin-out survival.

DISCUSSION & CONCLUSION

This study examined certain knowledge characteristics of incumbent firms that increase the propensity of spin-out firms being generated, and how congenital knowledge transferred from parent to progeny firm becomes a source of sustainable competitive advantage for these new entrepreneurial ventures. While past research has speculated on the possibility that there

---

[14] This result is not surprising because typically more successful and bigger foreign firms entered the market. Also many of the foreign firms are captive or pre-existing firms that are only expanding into the disk drive market, whereas most of the new US firms are start-ups.

[15] Since the regressions include year of entry dummies that are strongly correlated with highest areal at time of entry, the latter variable is not included in the model. Results with high areal at time of entry are similar to those reported.

may be a congenital aspect to organizational learning, this study theoretically links and empirically demonstrates (a) the influence of such learning on organizational speciation, or the founding of spin-outs, and (b) the influence of this initial stock of inherited know-how on the ability of these entrepreneurial ventures to sustain their knowledge advantage over other entrants. Our hypotheses thus revolved around a common theme: is there a parent and progeny knowledge transfer relationship that influences progeny performance over time?

With a dataset that includes both product and genealogical information about firms in the disk drive industry from 1977-1997, we test our hypotheses, and find resounding support. The results confirmed our prediction that not only do smart firms tend to have a higher propensity to generate spin-outs, but also that smarter parents tend to create smarter progenies. Our findings are significant for several reasons. First, they support the idea of some organizational management and industrial economic scholars regarding the importance of knowledge to the founding of new entrepreneurial ventures (Brittain and Freeman 1986; Stinchcombe 1965). Second, we find strong evidence for the premise that organizations acquire knowledge through the process of congenital learning, and Huber's (1991) untested premise that congenital learning strongly influences future learning. In other words, we find that capability accumulation is path-dependent, and related to knowledge at the time of founding. Path dependence in acquiring, accumulating, and deploying complex capabilities imply that the initial stock of knowledge at founding leaves a long-lasting imprint on a firm's future competitiveness. Congenital learning thus affects a firm's performance over time. Equally important, the results provide strong support for the resource-based view of the firm and arguments presented by several strategy scholars in recent years (Barney 1986; Dierickx and Cool 1989; Grant 1996; Eisenhardt and Martin 2000) that knowledge-based capabilities form the fountainhead of sustained superior performance.

Our findings indicate that spin-outs are more likely to emerge from incumbent firms that possess relatively higher levels of either technical or marketing capabilities. Knowledge thus could be a double-edged sword, since it makes a firm more vulnerable to spawning their own future competition. This finding is reinforced by evidence from the semi-conductor industry where almost half the entering firms had at least one founder who had worked at Fairchild, which was considered to be the industry's technological leader (Braun & Macdonald 1978). Also, IBM and Shugart, both early-movers, generated numerous spin-outs. Two, namely Seagate and Rotating Memory Systems, subsequently became early movers themselves in emerging technical sub-fields as the market underwent disruptive change (Franco and Filson 2000).

Further, our findings indicate that the simultaneous co-presence of high levels of technological and market pioneering capabilities *lowered* the incidence of spin-out formation. While the complementary, synergy creating nature of technology and marketing related capabilities have been noted (Moorman and Slotegraaf 1998), our results indicate yet another important reason for building dual capabilities rather than concentrate in only one core area of competency: leakage of trade secrets and R&D spillovers through employee mobility may be significantly deterred if a firm possesses these co-specialized assets. Such firms are less vulnerable to threats poised by employee migration for two reasons: One, it reduces the frustration that may motivate scientists to leave out when they do not see their technological breakthroughs become market place realities, and two, pre-empting market niches lower incentives for employees to venture on their own and enter these segments through their own entrepreneurial ventures[16]. We find that older organizations are no more prone to generating spin-outs than younger ones. We also find that disk diameter diversity, which measures the product market spread, decreases likelihood of spin-out generation, providing support to the deterrent effect of parental presence in multiple drives.

Our second and third themes focused on congenital learning, and its effect on organizational outcomes. We find that parent-progeny knowledge transfer explains variance in

[16] Anecdotal evidence in Christensen (1997) shows that disaffected employees left Seagate and Miniscribe, the two largest 5.25 inch manufacturers who also developed the 3.5 inch drive. Seagate and Miniscribe shelved the 3.5 inch drive due to lack of interest from current consumers. The former employees founded the leading 3.5 inch drive maker, Conner Peripherals. Similarly, the founder of 8 inch drive Micropolis came from Pertec, a 14 inch drive manufacturer, and the founders of Shugart and Quantum defected from Memorex for similar reasons. In contrast, some companies, such as Quantum and Control Data created subsidiaries to target emerging segments to prevent spin-out formation. Another case in point is Micropolis, itself a spin-out and an early mover, which successfully made the transition to a disruptive platform by managing the change from within the mainstream company and thus retaining its employees.

knowledge trajectories both among spin-outs, and between spin-outs and other entrants. First, the results indicate that differences in spin-out technological and marketing capability accumulation over time can be explained by the congenital learning that they inherited at the time they were founded. Second, we find strong support for our prediction that spin-outs are likely to retain their knowledge superiority over other entrants over time, after controlling for various firm, industry and chronology related factors. Spin-outs therefore do gain from their parent's expertise, which helps them out-perform other types of entrants. It thus appears that the knowledge 'edge' that they inherit gives them a head-start, which they are able to retain over time. In other words, we find evidence that the initial stock of congenital knowledge they inherit turns into a source of sustainable advantage. Finally, the finding that spin-outs enjoy higher survival rates over other entrants establishes that their knowledge based advantages transform into superior performance.

Technology transfer from parents to progenies is widespread in several high tech industries, including the semi-conductor, computer hardware and software industries (Braun and Macdonald 1978; Christensen 1997). We hope that our research spurs thoughts on related issues. One avenue for future research would be to extend the study to cover other industries, and see if there are any industry specific moderating factors that affect the results. For instance, is the degree of tacitness of knowledge a conditioning factor to the probability of spin-out generation? In addition, the study suggests that technology lock-in by incumbent firms causes them not to pursue emerging markets. Employees then exploit the in-house developed technology by leaving the parent firm and become formidable competitors. This technology lock-in effect needs to be quantified, and one potential way of doing so is to measure the differences in the profit streams of the incumbents in established versus emerging markets.

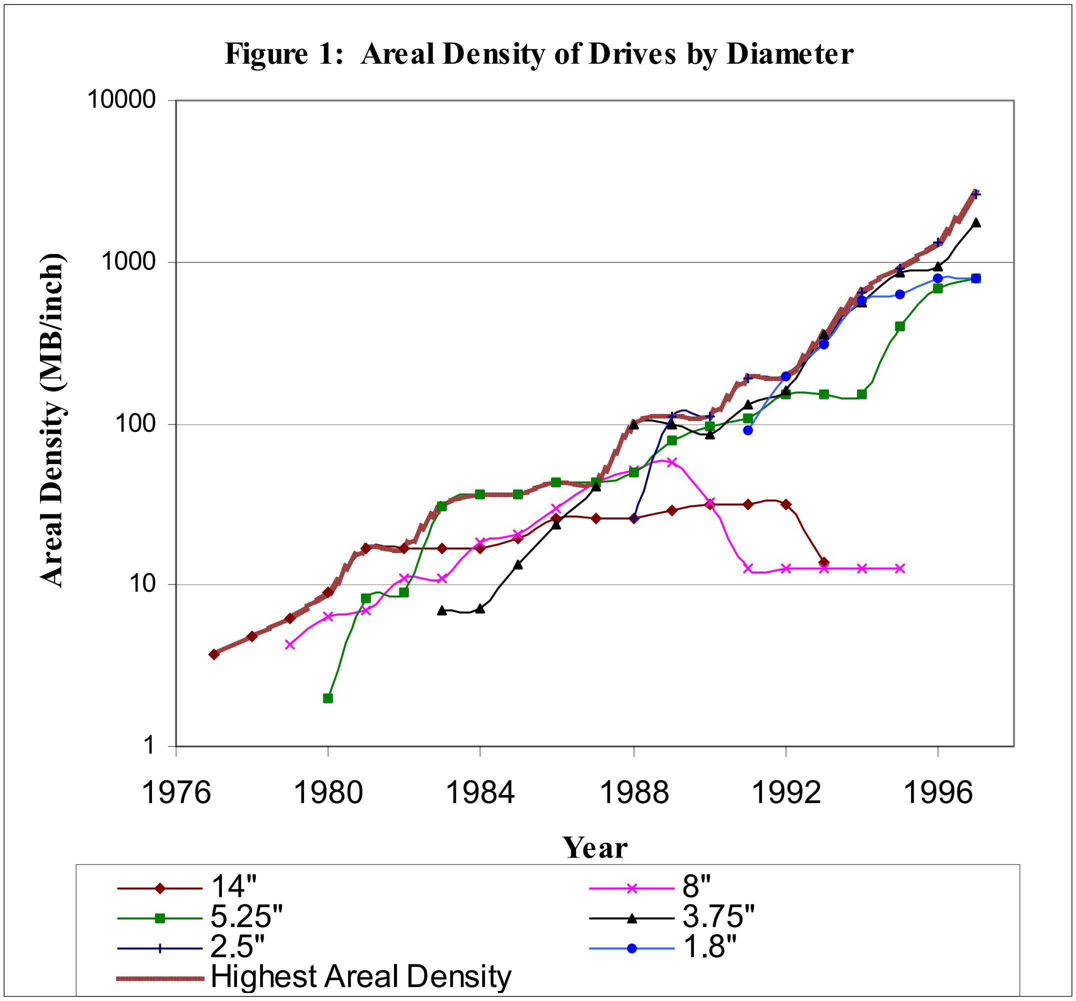
Figure 1: Areal Density of Drives by Diameter
10000
1000
100
10
1
Areal Density (MB/inch)
1976
1980
1984
1988
1992
1996
Year
14"
8"
5.25"
3.75"
2.5"
1.8"
Highest Areal Density

Table 1: Definition of Variables and Rationale

Variable Name	Variable Description	Rationale
Key Variables in Study		
Spin-out Creation	Number of spin-outs a firm generated a in any given year (0 if no spin-outs were generated)	Dependent variable for H1-H3
Survival	Dummy = 1 if firm survived to the following period (acquisitions treated as censored observations)	Dependent variable for H6
Technological Know-how	Firm's technological know-how in any year relative to the frontier technological know-how. Areal density (information per square inch) of the firm's best drive in each diameter in each year is divided by the highest areal density observed for that diameter. This measure is then averaged across diameters to obtain a single measure for the firm in each year.	Resource-based view argues that knowledge-based technological capabilities are critical to performance Explanatory variable for H_1-H_3 and H_6; Dependent variable for H_4-H_5
Market Pioneering Know-how	Number of times a firm introduced a drive of a new diameter within the first year of the diameter's introduction/ Total number of opportunities the firm had to do so	Measures the early-mover advantage of the firm Explanatory variable for H_1-H_3 and H_6; Dependent variable for H_4-H_5
Parent Technological Know-how	Average relative technological know-how (as described above) of the parent in the year preceding the spin-out's entry into the industry.	Measures the capabilities of a parent firm regarding technological knowledge Explanatory variable for H_4-H_5
Parent Market Pioneering Know-how	Market pioneering know-how (as described above) of the parent in the year preceding the spin-out's entry into the industry.	Measures the capabilities of a parent firm regarding technological knowledge Explanatory variable for H_4-H_5
Spin-out	Dummy = 1 if one of the founders of a firm was an ex-employee of an incumbent firm in the year prior to spin-out formation.	Entrepreneurial ventures by ex-employees are different from other types of entry and represent technological transfer Explanatory variable for H_6
Firm Specific Control Variables		
Firm Sales	Logged value of Sales of the firm per year, in millions of dollars	Larger firms may generate more spin-outs
Firm Growth	Growth in sales of the firm per year, in millions of dollars	In failing firms, employees may leave to start off on their own due to lack of employment opportunities

Variable Name	Variable Description	Rationale
Foreign	Dummy = 1 if firm was a foreign firm. Note that since only one foreign firm generated a spin-out, this variable is not included in the hypotheses H_1-H_4 that pertain to spin-out formation/learning from parents	Foreign firms may be different from US due to institutional reasons.
Age, Age^2	Chronological age of firm since founding	Spin-out generation/survival affected non-linearly by firm age
Parent Presence	A dummy variable if parent was present in the diameter within which the spin-out first entered	Measures the impact of the parent's presence of spin-out performance and controls for potential deterrent effect
Firm Diversity	Number of diameters produced by the firm – average number of diameters produced by all firms in that year. Note that alternative operationalization as a proportion gives similar results	Measures firm diversity and scope of operations relative to the mean diversity and scope of operations in the industry
Incumbent 76	Dummy = 1 if firm entered prior to 1977	Controls for effects for firms that entered before the period under investigation
Industry Specific Control Variables		
Highest Areal	The highest areal density (information per square inch) of a drive across all the diameters produced in a given year: measure of the technological knowledge frontier in the industry in a given year	Knowledge accrual may be related to overall level of knowledge in the industry – absorptive capacity concept
Industry Sales	Sales of the industry per year, in millions of dollars	Represents resource munificence
Industry Growth	Growth in sales of the industry per year, in millions of dollars	Represents growth opportunities for firms
Nfirm, $Nfirm^2$	Number of firms in the industry per year	Non linear competitive density effects
Nentries	Number of firms entering the industry per year	Bandwagon effect may explain spin-out formation, and possibly extent of churn in the industry
Chronology Specific Control Variables		
Yrd77-Yrd97	Year Dummies for current year of operation	Controls for time effects
Yre77-Yre97	Year Dummies for the entry year of the firm	Controls for founding conditions

Table 2: Descriptive Statistics

No.	Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Spin out Creation	0.05	0.24	1.00																	
2	Survival	0.88	0.33	-0.01	1.00																
3	Spin-out	0.30	0.46	0.19	0.06	1.00															
4	Tech Know-how	0.44	0.23	0.02	0.09	0.29	1.00														
5	Markt. Pion. Know-how	0.09	0.29	0.13	0.02	0.22	0.08	1.00													
6	Sales	6.95	11.28	0.03	0.23	-0.12	0.02	0.02	1.00												
7	Foreign	0.23	0.42	-0.10	-0.05	-0.36	-0.22	-0.04	0.02	1.00											
8	Age	6.16	5.81	-0.03	0.00	-0.11	0.21	0.07	0.28	-0.20	1.00										
9	Age ^{2}	71.59	158.43	-0.03	0.04	-0.11	0.24	0.08	0.18	-0.16	0.89	1.00									
10	Parent presence	0.08	0.27	0.01	0.05	0.45	0.14	-0.02	-0.12	-0.16	-0.06	-0.06	1.00								
11	Incumbent 76 Dummy	0.31	0.46	0.03	0.08	-0.27	0.09	-0.09	0.19	-0.37	0.47	0.36	-0.19	1.00							
12	Product Diversity	0.00	0.97	0.02	0.13	-0.05	0.16	0.12	0.28	-0.23	0.51	0.42	-0.01	0.42	1.00						
13	Highest Areal	193.08	435.07	-0.07	0.01	0.01	0.09	-0.04	0.13	0.07	0.31	0.28	-0.01	-0.10	0.00	1.00					
14	Industry Sales	16.34	0.67	-0.11	-0.13	0.05	0.05	-0.03	0.11	0.28	0.36	0.25	0.05	-0.32	0.00	0.41	1.00				
15	Industry growth	0.14	0.10	0.03	0.08	0.02	-0.10	0.08	-0.07	-0.12	-0.22	-0.18	0.00	0.14	0.01	-0.31	-0.52	1.00			
16	Number of Firms	62.83	16.87	0.06	0.02	0.05	-0.10	0.11	-0.11	-0.06	-0.24	-0.23	0.05	0.02	0.00	-0.68	-0.22	0.57	1.00		
17	Number of Firms2	4214.45	1897.70	0.05	0.01	0.07	-0.10	0.12	-0.10	-0.06	-0.20	-0.20	0.05	0.00	0.00	-0.59	-0.14	0.56	0.99	1.00	
18	Number of entries	8.02	4.49	0.12	0.05	0.03	-0.08	0.12	-0.12	-0.13	-0.24	-0.21	0.01	0.10	0.00	-0.57	-0.45	0.51	0.72	0.72	1.00

Table 3: Spin-out Generation (Hypotheses 1-3)

Variable	Model 3a (Neg Bin.)	Model 3b (ZINB)	Model 3c (Neg Bin.)	Model 3d (ZINB)
Technological Know-How	2.262**	2.164**	3.457**	3.397**
	(0.795)	(0.773)	(0.946)	(0.943
Market Pioneering Know-How	1.256**	1.017*	3.352**	3.132**
	(0.507)	(0.565)	(1.033)	(1.080)
Technological Know-How *			-4.062**	-3.976**
Market Pioneering Know-How			(1.861)	(1.872)
Age	-0.126	-0.091	-0.156	-0.137
	(0.185)	(0.204)	(0.177)	(0.191)
Age ^{2}	0.001	0.0001	0.002	0.002
	(0.006	(0.007)	(0.006)	(0.006)
Firm Sales	0.505**	0.515**	0.446**	0.450**
	(0.167	(0.173)	(0.162)	(0.168)
Industry Sales	0.846	0.779	1.056	1.012
	(1.450)	(1.471)	(1.437)	(1.480)
Sales Growth	0.321	0.357	0.267	0.265
	(0.397)	(0.401)	(0.385)	(0.385)
Industry Growth	-3.654	-3.975	-3.326	-3.498
	(2.815)	(2.831)	(2.731)	(2.742)
Highest Areal	-0.019	-0.018	-0.019	-0.018
	(0.015)	(0.016)	(0.015)	(0.015)
Product Diversity	-0.477*	-0.452*	-0.566**	-0.549**
	(0.278)	(0.278)	(0.275)	(0.271)
Incumbent 76 Dummy	-0.856	-0.984	-0.668	-0.774
	(0.746)	(0.792)	(0.754)	(0.805)
Number of Firms	0.587*	0.561*	0.661**	0.632**
	(0.324)	(0.314)	(0.328)	(0.318)
Number of Firms ^{2}	-0.005*	-0.004*	-0.005**	-0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
Number of Entrants	0.015	0.023	0.026	0.034
	(0.081)	(0.085)	(0.079)	(0.084)
Number of Observations	1190	1190	1190	1190
Log Likelihood	-101.93	-101.77	-99.47	-99.29
Vuong Statistic		0.22		1.52*

Standard Errors are in parentheses. **Significant at the 5% level * Significant at the 10% level
Year dummies included by not reported

Table 4: Spin-out Know-how Related to Parent's Know-how (Hypothesis 4a and b)

Variable	Model 4a Technological Know-how	Model 4b Market Pioneering Know-how
Parent Technological Know-how[1]	0.140**	-------
	(0.045)	
Parent Market Pioneering Know-how[1]	-------	0.108**
		(0.044)
Age	-0.032**	0.042**
	(0.009)	(0.015)
Age^2	0.002**	-0.002**
	(0.0005)	(0.0008)
Firm Sales	-0.001	0.003*
	(0.001)	(0.002)
Industry Sales	0.052	-0.195**
	(0.047)	(0.077)
Industry Growth	0.032	0.026
	(0.166)	(0.276)
Highest Areal	-0.00002	0.0001
	(0.00001)	(0.0001)
Number of Firms	0.007	-0.002
	(0.008)	(0.014)
Number of $Firms^2$	-0.0001	0.0001
	(0.0001)	(0.0001)
Number of Entrants	0.001	-0.003
	(0.005)	(0.008)
Number of Observations	344	344
System $R^2 = 0.28$		

Estimations using seemingly unrelated regression
Standard Errors are in parentheses
**Significant at the 5% level
*Significant at the 10% level
[1]Parentknow-how measured in the year preceding spin-out entry into the market.
Year of entry dummies included but not reported.

Table 5: Technological and Market Pioneering Know-how of Spin-out and Non Spin-out Firms (Hypothesis 5a and b)

Variables	Model 5a Technical Know-how	Model 5b Market Pioneering Know-how
Spin-out	0.162**	0.106**
	(0.016)	(0.024)
Age	-0.007	0.053**
	(0.006)	(0.009)
Age^2	0.0004	-0.003**
	(0.0004)	(0.0006)
Firm Sales	-0.0002	0.0005
	(0.0007)	(0.0009)
Industry Sales	-0.005*	-0.163**
	(0.032)	(0.048)
Industry Growth	-0.097	0.075
	(0.119)	(0.172)
Highest Areal	-0.00001	0.00003
	(0.00004)	(0.00006)
Number of firms	-0.003	-0.002
	(0.006)	(0.008)
Number of $firms^2$	0.00002	0.00005
	(0.00005)	(0.00007)
Number of entries	0.0002	0.0008
	(0.004)	(0.005)
Number of Observations	767	767
System R^2 = 0.18		

Estimations using seemingly unrelated regression
standard errors are in parentheses
**Significant at the 5% level
* Significant at the 10% level
Year of entry dummies included by not reported

Table 6: Probability of Survival of Spin-out and Non Spin-out Firms (Hypothesis 6)

Variable	Model
Intercept	8.70** (3.10)
Spin-out	0.89** (0.30)
Technological Know-how	0.97* (0.43)
Market Pioneering Know-how	-0.18 (0.33)
Foreign Firm	0.56** (0.27)
Age	0.04 (0.15)
Age^2	0.004 (0.007)
Firm Sales	0.01** (0.005)
Parent Presence	0.45 (0.48)
Highest Areal	0.003** (0.001)
Industry Sales	-0.02** (0.006)
Industry Growth	4.36** (1.93)
Nfirms	0.36** (0.10)
Nfirms2	-0.003** (0.001)
Nentries	0.03 (0.05)
Number of observations	763
Log likelihood	-271.11

Year of entry dummies included but not reported
**Significant at 5 percent level
*Significant at 10 percent level

References

Abernathy, W., & Utterback, J. M. 1978. Patterns of industrial innovation***. Technology Review***, 80: 97-107.

Aiken, L.S., & West, S. G. 1991. ***Multiple regressions: Testing and interpreting interactions***. Newbury Park, CA: Sage.

Aldrich, H.E., & Pfeffer, J. 1976. Environments of organizations. ***Annual Review of Sociology***, 2: 79-105.

Allen, J.W. 2001. Private information and spin-off performance. ***The Journal of Business,*** 74(2), 281-306.

Allison, P. D. 1995. ***Survival analysis using the SAS system: A practical guide***. Cary, NC: SAS Institute.

Argyris, C., & Schon, D. A. 1978. ***Organizational learning: A theory of action perspective reading***. MA: Addison-Wesley.

Arrow, K. 1962. Economic welfare and the allocation of resources for invention. In ***The rate and direction of economic activity***. National Bureau of Economic Research, Princeton, N.J.: Princeton University Press, 609-625.

Badaracco, J. L. 1991. ***The knowledge link***. Boston, MA: Harvard Business School Press.

Barney, J. B. 1986. Strategic factor markets: Expectations, luck and business strategy. ***Management Science***, 32(10): 1231-1241.

Baum, J. A. C., & Oliver, C. 1991. Institutional linkages and organizational mortality. ***Administrative Science Quarterly***, 36: 187-218.

Benkhoff, B. 1997. A Test of the HRM Model: Good for employers and employees. ***Human Resource Management Journal,*** 7(4): 44-60.

Bierly, P., & Chakrabarti, A. 1996. Generic Knowledge strategies in the U.S. pharmaceutical industry. ***Strategic Management Journal,*** 17(Winter): 123-135.

Boeker, W. 1997. Executive migration and strategic change: The effect of top manager movement on product-market entry. ***Administrative Science Quarterly***, 42: 213-236.

Bowman, D., & Gatigon, H. 1996. Order of entry as a moderator of the effect of marketing mix on market share. ***Marketing Science,*** 15(3): 222-42.

Braun, E., & Macdonald, S. 1978. ***Revolution in miniature***. Cambridge, England: Cambridge University Press.

Brittain, J. W., & Freeman, J. 1986. ***Entrepreneurship in the semiconductor industry***. Paper presented at the Academy of Management Meetings.

Chandy, R. K., & Tellis, G.J. 1998. Organizing for radical product innovation: The overlooked role of willingness to cannibalize. ***Journal of Marketing Research***, 35(4): 474-487.

Chesbrough, H. 1999. Arrested Development: The experience of European hard disk drive firms in comparison with us and Japanese firms. ***Journal of Evolutionary Economics***, 9: 287-329.

Christensen, C. 1993. The rigid disk drive industry: A history of commercial and technological turbulence. ***Business History Review***, 67(Winter): 531-588.

Christensen, C. 1997. *The innovator's dilemma:* ***When new technologies cause great firms to fail***. Boston, Massachusetts: Harvard Business School Press.

Christensen, C. M., Suarez, F. F., & Utterback, J. M. 1998. Strategies for survival in fast-changing industries. ***Management Science***, 44(12): S207-S220.

Christensen, C. M., & Bower, J. L. 1996. Customer power, strategic investment, and the failure of leading firms. ***Strategic Management Journal***, 17: 197-218.

Coff, R. W. 1997. Human assets and management dilemmas: Coping with hazards on the road to resource- based theory**. *Academy of Management Review***, 22(2): 374-402.

Cohen, W.M., & Levinthal, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly***, 35: 128-152.

Conner, K. R., & C.K. Prahalad. 1996. A resource-based theory of the firm: Knowledge versus opportunism. ***Organization Science***, 7: 477-501.

Cyert, R.M., Kumar, P., & Williams, J. R. 1993. Information, market imperfections and strategy. ***Strategic Management Journal***, 14 (Winter Special Issue): 47-58.

Dahlstrand, A. L. 1997. Growth and inventiveness in technology-based spin-off firms. *Research Policy*, 26: 331-344.

Day, G. S. 1994. The capabilities of market-driven organizations. ***Journal of Marketing***, 58 (4): 37-52.

Deshpande, R., & Webster, F. E., Jr. 1989. Organizational culture and marketing: Defining the research agenda**. *Journal of Marketing***, 53(January): 3-15.

Dierickx, I., & Cool, K. 1989. Asset stock accumulation and sustainability competitive advantage. ***Management Science***, 35(12): 1504-13.

Dosi, G. 1982. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change*.* ***Research Policy,*** 11(3): 147-162.

Doutriaux, J. 1992. Emerging High Tech Firms: How durable are their comparative start-up advantages? ***Journal of Business Venturing***, 7: 303-322.

Eisenhardt, K. M., & Martin, J. A. 2000. Dynamic capabilities: What are they? ***Strategic Management Journal***, 21: 1105-1121.

Fiol, C. Marlenes. 1991. Managing culture as a competitive resource: An identity-based view of sustainable competitive advantage. ***Journal of Management,*** 17: 191-211.

Fried, V. H., & Hisrich, R.D. 1994. Toward a model of venture capital investment decision making. ***Financial Management***, 23 (3): 28 – 37.

Garvin, D. A. 1983. Spin-offs and the new firm formation process. ***California Management Review***, 25 (2): 3-20.

Greene, W. 1993. ***Econometric analysis***, 2^{nd} Edition. Englewood Cliffs, NJ.

Franco, A. M., & Filson, D. 2000. ***Knowledge diffusion through employee mobility***. Working paper, University of Iowa, Iowa.

Garvin, D. A. 1983. Quality on the line. ***Harvard Business Review***, 61(5): 65-75.

Geroski, P. A. 1995. Do spillovers undermine the incentive to innovate? In S. Dowrick (Ed.), ***Economic approaches to innovation***: 76-97. Aldershot, UK: Edwar Elgar.

Golder, P. N., & Tellis, G. J. 1993. Pioneer advantage: Marketing logic or marketing legend? ***Journal of Marketing Research***, 30: 158-170.

Gort, M. & Klepper, S. 1982. Time paths in the diffusion of product innovations. ***Economic Journal***, 92: 630-653.

Grant, R. M. 1996. Toward a knowledge-based theory of the firm. ***Strategic Management Journal,*** 17 (Summer Special Issue): 109-22.

Henderson, R. M., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. ***Administrative Science Quarterly***, 35: 9-30.

Henderson, A. D. 1999. Firm strategy and age dependence: A contingent view of the liability of newness, adolescence, and obsolescence. ***Administrative Science Quarterly***, 44: 281-314.

Higgins, M. C., & Gulati, R. 1999. ***Getting off to a good start: The effects of upper echelon affiliations on interorganizational endorsements and IPO success***. Working paper no. 00-025, Harvard Business School.

Huber, G.P. 1991. Organizational learning: The contributing processes and the literatures. ***Organization Science***, 2: 88-115.

Ingram, P., & Baum, J. A. C. 1997. Opportunity and constraint: Organizations' learning from the operating and competitive experience of industries. ***Strategic Management Journal***, 18: 75-98.

Jaworski, B. J., & Kohli, A. K. 1993. Market orientation: Antecedents and consequences. ***Journal of Marketing***, 57 (July): 53-71.

John, G., Weiss, A. M., & Dutta, S. 1999. Marketing in technology-intensive markets: Towards a conceptual framework. ***Journal of Marketing***, 63: 78-91.

Kalyanaram, G., Robinson, W. T. & Urban, G. L. 1995. Order of market entry: Established empirical generalizations, emerging empirical generalizations and future research. ***Marketing Science,*** 14: G212-G222.

Kessides, N. 1991. Entry and market contestability: The evidence from the United States. In P. A. Geroski & J. Schwalbach (Eds.), ***Entry and market contestability: An international comparison***: 23-48. Blackwell: Oxford.

Klepper, S., & Sleeper, S. 2000. ***Entry by spinoffs***. Working paper, Carnegie Mellon University, Pittsburgh.

Knight, R. M. 1989. Technological innovation in Canada: A comparison of independent entrepreneurs and corporate innovators. ***Journal of Business Venturing,*** 4(4): 281-288

Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. ***Organization Science***, 3: 383-397.

Kohli, A. K., & Jaworski, B. 1990. Market orientation: The construct, research propositions, and managerial implications. ***Journal of Marketing*****,** 54(April): 1-18.

Lambkin, M. 1988. Order of entry and performance in new markets. ***Strategic Management Journal***, 9:127-140.

Lerner, J. 1997. An empirical exploration of a technology race. ***RAND Journal Economics,*** 28(2): 228-247.

Levinthal, D., & Fichman, M. 1988. Dynamics of interorganizational attachments: Auditor client relationships. ***Administrative Science Quarterly***, 30(3): 345-369.

Levitt, B., & March, J. G. 1988. Organizational learning. ***Annual Review of Sociology***, 14: 319-340.

Lieberman, M. B., & Montgomery D. B. 1988. First mover advantages. ***Strategic Management Journal,*** 9: 41-58.

Liebeskind, J. P. 1996. Knowledge, strategy, and the theory of the firm, ***Strategic Management Journal****, 17: 93-107.*

Lippman, S., & Rumelt. R. 1982. Uncertain Imitability: An analysis of interfirm differences in efficiency under competition. ***Bell Journal of Economics***, 13(Autumn): 418-38.

Malone, M. 1985. ***The big score***. Garden City, NY: Doubleday & Company Inc.

Miller, D., & Shamsie, J. 1996. The resource-based view of the firm in two environments: The Hollywood film studios from 1936 to 1965, ***Academy of Management Journal***, 39(3), 519-544.

Moen, J. 2000. Is mobility of technical personnel -A source of R & D spillovers? Working Paper 7834, National Bureau of Economic research, Cambridge: MA.

Moorman, C., & Miner, A. S. 1997. The impact of organizational memory on new product performance and creativity. ***Journal of Marketing Research***, 34(February): 91-106.

Moorman, C., & Slotegraaf, R. J. 1999. The contingency value of complementary capabilities in product development**.** ***Journal of Marketing Research,*** 36(May): 239-257.

Narver, J. C., & Slater, S. F. 1990. The effects of a marketing orientation on business profitability. ***Journal of Marketing,*** 54 (October): 20-35.

Nonaka, I. 1994. A dynamic theory of organizational knowledge creation. ***Organization Science,*** 5: 14-37.

Park, C. W., & Zaltman, G. 1987. ***Marketing Management***. Hinsdale, IL: The Dryden Press.

Phillips, D. J. 2000. ***The parent-progeny transfer and organizational mortality: The case of Silicon Valley law firms*** 1946-1996. Working paper, University of Chicago.

Prahalad, C. K., & Bettis, R. A. 1986. The dominant logic: A new link between diversity and performance. ***Strategic Management Journal,*** 7: 485-501.

Propson, D. 2000. Ties That Bind. *Business,* June 27.

Reed, R., & DeFillipi, R. J. 1990. Casual ambiguity, barriers to imitation, and sustainable competitive advantage. ***Academy of Management Review***, 15 (January): 88-102.

Robinson, W.T., & Fornell, C. 1985. Sources of market pioneer advantages in consumer goods industries. ***Journal of Marketing Research,*** 22: 305-17.

Romanelli, E. 1991. The evolution of new organizational forms. *Annual Review of Sociology,* 17: 79-103.

Rosen, S. 1972. Learning and experience in the labor market. ***Journal of Human Resources***, 7(3): 326-42.

Schoonhoven, C. B., Eisenhardt, K. M., & Lyman, K. 1990. Speeding products to market: waiting time to first product introduction in new firms. ***Administrative Science Quarterly,*** 35: 177-207.

Schulz, M. 2001. The uncertain relevance of newness: Organizational learning and knowledge flows. ***Academy of Management Journal***, 44 (4): 661-680.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. ***Organization Science***, 11(4): 448-469.

Shaver, K. G., & Scott, L. R. 1991. Person, process, choice: The psychology of new venture creation. ***Entrepreneurship Theory and Practice***, 16(2): 23-45.

Shrader, R. C., & Simon, M. 1997. Corporate versus independent new ventures: Resource, strategy, and performance differences. ***Journal of Business Venturing***, 12(1): 47-66.

Singh, J.V., & Lumsden, C. J. 1991. Theory and research in organizational ecology. ***Annual Review of Sociology***, 16: 161-195.

Slater, S. F. 1997. Developing a customer-value based theory of the firm. ***Journal of the Academy of Marketing Science,*** 25(2): 162-167.

Spender, J. C. 1996. Making knowledge the basis of a dynamic theory of the firm. ***Strategic Management Journal***, *17: 45-62.*

Stinchcombe, A. L. 1965. Social Structure and Organizations. In J.G. March (Ed.), ***Handbook of Organizations***: 153-193. Chicago, IL: Rand McNally.

Stinchcombe, A. L., & Heimer, C. A. 1988. Interorganizational relations and careers in computer software firms. In I. H. Simpson & R. L. Simpson (Eds.), ***Research in the Sociology of Work***, 5: 179-204. Greenwich, Conn: JAI Press.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing, and public policy**.** ***Research Policy***, 15: 285-305.

Teece, D. J. 1988. Capturing value from technological innovation: Integration, strategic partnering, and licensing decisions**.** ***Interfaces***, 18(May-June): 46-61.

Teece, D. J., Pisano, G., & Shuen. A. 1997. Dynamic capabilities and strategic management. ***Strategic Management Journal***, 18: 509-33.

Tushman, M. L., & Anderson, P. 1986. Technological discontinuities and organizational environments. ***Administrative Science Quarterly***, 31: 439-465.

Venkataraman, S. 1997. The distinctive domain of entrepreneurship research: An editor's perspective. In J. K. R. Brockhaus (Ed.), ***Advances in entrepreneurship, firm emergence, and growth***: 119-138. Greenwich, CT: JAI Press.

Walker, O. C., Jr., & Ruekert, R. W. 1987. Marketing's role in the implementation of business strategies**.** ***Journal of Marketing,*** 51(July): 15-33.

Winter, S. G. 1991. On Coase, competence, and the corporation. In O. E. Williamson & S. G. Winter (Eds.), ***The Nature of the Firm: Origins, Evolution and Development***: 179-195. Oxford: Oxford University Press.

Zander, U. 1991. ***Exploiting a technological edge – voluntary and involuntary dissemination of technology.*** Stockholm: IIB. Unpublished doctoral dissertation.

Zucker, L. G., Darby, M. R., & Brewer, M. B. 1998. Intellectual human capital and the birth of US biotechnology enterprise***. American Economic Review,*** 88: 290-306.