The Role of Exploration in Firm Survival in the Worldwide Optical Library Market, 1990-1998*

Gun Jea Yu**
Cornell University
School of Industrial and Labor Relations
Ithaca, NY 14853
gv52@cornell.edu
tel.: 617-777-0069

Olga M. Khessina***
Cornell University
Samuel Curtis Johnson Graduate School of Management
364 Sage Hall
Ithaca, NY 14853
omk4@cornell.edu
tel.: 607-255-7284

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**The authors equally contributed to this paper. The order of authorship was randomly determined.
***Corresponding author.

ABSTRACT

We investigate how a firm’s involvement in exploration activities affects its survival chances. We predict that while the main effect of exploration on organizational longevity is beneficial, the extent of these survival benefits will significantly vary across different organizational types. Firms that are structurally inert and firms that have resources that can be used as a buffer in difficult times will derive greater survival benefits from exploration than firms that are structurally flexible and lack slack resources that can be used as a buffer. The event history analysis of disbanding rates of all firms that participated in the worldwide optical library market from 1990 through 1998 supports these predictions.

Keywords: exploration, organizational survival, event history analysis, organizational ecology, structural inertia
Introduction

Research in strategy and management has emphasized the importance of exploration and exploitation activities for organizational performance (March, 1991; Levinthal & March, 1993; Dowell & Swaminathan, 2006; Burgelman & Grove, 2007; McKendrick, Wade & Jaffee, 2009; Ming, 2010). It was shown that exploration and exploitation affect firm short-term performance, such as, for example, sales growth (He & Wong, 2004), return on assets (Auh & Menguc, 2005) and Tobin’s q (Wang & Li, 2008; Uotila, et al., 2009). Some studies revealed a strong positive relationship between exploration, exploitation and organizational outcomes (Katila & Ahuja, 2002; Wang & Li, 2008; Uotila, et al., 2009). Others showed that exploration and exploitation enhance organizational performance only under certain conditions (Jansen, van den Bosch, & Volberda, 2006). Overall, significant knowledge has accumulated on the effects of exploration and exploitation on short-term organizational outcomes. By contrast, the impact of these activities on firm long-term performance, such as organizational survival, is much less understood (Ming, 2010)\(^1\). Given the key assumption that exploration is strongly associated with long-term performance (March, 1991), we need to know more about how exploration affects organizational survival.

The literature tends to assume that exploration affects survival of all firms in the same way (Ming, 2010). Yet, research in corporate demography (also known as organizational ecology) has shown that organizational characteristics, such as firm age, size, entry mode, and product scope among others, may have a dramatic impact on organizational structures and processes (for review, Hannan, Pólos & Carroll, 2007). Structural differences among different

\(^1\)Few studies on exploration and exploitation adopted Tobin’s q as the measure of firm long-term performance (Uotila et al., 2009; Wang & Le, 2008). However, sometimes Tobin’s q fails to predict the future effects of investment accurately (Blanchard, Rhee, & Summers, 1993) and thus is not as accurate measure of the long-term performance as organizational survival (Ming, 2010).
types of firms may lead to significant variations in firms’ abilities to extract benefits from exploration activities and consequently affect their long-term performance, such as organizational survival, in different ways (Carroll & Teo, 1996; McKendrick & Wade, 2010).

In this paper, we integrate the literature on exploration with research on organizational ecology to develop a theory suggesting that types of firms with internal and external structures that prevent them from achieving the alignment with changing environmental demands may mitigate their structural inertia by pursuing exploration. Such firms are likely to derive more survival benefits from exploration activities than structurally flexible organizations capable of superior environmental alignment. We also argue that firms that possess slack resources are more likely to survive unsuccessful exploration and therefore will derive more overall survival benefits from exploring than firms with poor resources that are likely to fail if their exploration efforts do not payoff in a reasonable amount of time. We derive specific empirical predictions from this theorizing that survival benefits from exploration will vary with firm size, age, entry mode, and product scope. We find support for most of these predictions in an event history analysis of a longitudinal dataset that includes all firms that ever participated in the optical library market from 1990 through 1998.

This paper seeks to contribute to the research on exploration by developing a predictive and testable theory that explains how exploration affects survival chances of different types of firms, by providing an empirical test of this theory on the longitudinal dataset, and by suggesting implications for managers with regard to decision making about pursuing exploration strategies in different types of companies.

BACKGROUND

March (1991) initially defined exploration as associated with organizational activities of
“search, variation, risk-taking, experimentation, play, flexibility, discovery, innovation”, whereas exploitation was associated with “refinement, choice, production, efficiency, selection, implementation, execution” (p.71). Levinthal and March (1993) refined these definitions by linking them to the knowledge domain. They proposed that exploitation refers to “the use and development of things already known,” whereas exploration is related to “a pursuit of new knowledge” (p. 105).

Much of the follow-up research has focused on the effects of exploitation and exploration on organizational performance. Researchers have theorized that exploration and exploitation have a differential impact in the short run and long run. Exploration activities may help an organization build new capabilities that better reflect the demands of a changing environment and, thus, enhance firm long-term performance (March, 1991). However, payoffs from exploration are more uncertain and distant compared to those of exploitation and many companies are reluctant to undertake exploration (Levinthal & March, 1993). By contrast, exploitation helps a firm enhance its short-term performance by increasing efficiency, decreasing performance variance, and improving adaptation to the current environment (March, 1991). However, high efficiency and reduced variation might become an organizational liability that prevents firms from adapting to a changing environment (Leonard-Barton, 1992).

Many empirical studies have shown differential effects of exploration and exploitation on organizational performance. For example, Auh and Menguc (2005) demonstrated that exploration is associated with organizational effectiveness, measured by market-share growth and sales growth, whereas exploitation is related to organizational efficiency, captured by return on assets and return on sales. It was also found that the relationship between exploitation, exploration, and organizational performance is contingent on environmental characteristics,
managerial preferences and firm strategy (Dowell & Swanminthan 2006; Lavie et al., 2010). For example, while competitive pressures intensify the contribution of exploitation to performance, environmental dynamism increases the positive effect of exploration (Jansen, et al., 2006).

Many empirical studies on effects of exploitation and exploration have focused on financial performance, measured as sales growth, return on assets, and manager self-reported performance. For example, He and Wong (2004) found that both explorative and exploitative innovation strategies are positively associated with the sales growth rate. Cao, et al. (2009) investigated the impact of exploitation and exploration on firm performance reported by managers in a survey.

As the literature review demonstrates, significant knowledge has been accumulated about empirical effects of exploration and exploitation on organizational short-term performance, and especially on financial outcomes. It is much less known about how exploration and exploitation influence firm long-term performance (but see Dowell and Swanminthan 2006; Ming, 2010). Since scholars theorize that exploration is a long-term process and that its outcomes can be seen only over an extended period of time (March, 1991; Burgelman & Grove, 2007), there is a need to understand how exploration affects organizational long-term performance, such as firm survival. In this study, we develop and test a theory that explains how exploration affects survival chances of different types of firms.

An investigation of exploration effects on firm survival can add to research on short-term performance and help to build a more complete picture of how exploration and exploitation affect performance and fates of firms (Raisch & Birkinshaw, 2008). We are aware of only one empirical study that looked directly at exploration effects on firm survival. Ming (2010)
investigated the impact of exploration on longevity of hard disk drive (HDD) producers, from 1978 to 1999. During this period, four major transitions in technological form factors, that involved different diameter HDDs and served different market segments, happened. Ming operationalized exploration as a firm’s development of new form factors and exploitation as repetition of a firm’s existing form factors. She found that exploitation without exploration hamper firms’ long-term viability and, thus, confirmed the importance of studying exploration effects on firm survival.

Compared to the accumulated knowledge on exploration effects on financial performance, we still know very little about the relationships between exploration and firm viability. For example, is exploration equally survival enhancing for all types of firms? Are there important organizational differences in exploration effects on survival that managers need to take into account when deciding on a firm’s exploration strategy? We specifically address this issue in this paper by developing a theory that predicts that structurally inertial firms and firms with abundant resources will enhance their survival chances more by engaging in exploration than flexible firms and firms with poor resources. We look at a variety of organizational dimensions, such as firm size, age, entry mode, and product scope that are associated with structural inertia and resource endowment to predict what types of firms will derive the greatest survival benefits from exploration.

Additionally, our study extends Ming’s work empirically. Operationalization of exploration based on firm transition in HDD form factors excludes from these measures firm exploration activities that took place but did not result in a physical product either at all (e.g., the goal was not product, but process innovation) or did not happen before the end of the observation period. This is especially problematic for measuring exploration, returns of which are theorized
to be highly uncertain and sometimes visible only long-term (March, 1991). It is necessary to show that effects of exploration on firm survival exist in different empirical settings and that they hold when exploration is operationalized in a different, more inclusive way.

To summarize, this paper intends to add to the previous research on by developing a testable theory that predicts what types of firms are more likely to derive greater survival benefits from exploration.

THEORETICAL ARGUMENTS AND HYPOTHESES

Exploration and Organizational Survival

Organizational survival depends on both organizational capabilities, which refer to a firm’s ability to improve and coordinate its internal and external organizational routines and structures, and environmental fit, which is the extent to which those routines and structures are well-suited to the current state of the environment (Carroll & Hannan, 2000; Sørensen & Stuart, 2000). Organizations with well-coordinated organizational routines and structures may fail if their capabilities do not fit environmental demands (Leonard-Barton, 1992). Organizations with routines and structures that are well-matched with environmental demands may fail as well if they do not have an ability to organize their routines efficiently (Carroll et al., 1996).

Organizational ecologists suggest that a firm’s survival depends on the alignment of its internal structures of production, innovation and employment systems, on the one hand, and relationships with external actors, on the other hand, with environmental demands (Barnett & Carroll, 1995; Carroll & Hannan, 2000). Firms with the superior alignment of their internal and external structures with the environment are more successful in mobilizing resources and attracting and retaining employees (Stinchcombe, 1965; McKendrick, et al., 2009). This advantage in resource and employee mobilization often translates into higher survival rates (Rao,
The environment may significantly change over time (Carroll & Hannan, 2000; Lavie et al., 2010); hence, organizations have to transform their internal and external structures to maintain their environmental fit. Organizational change, however, is difficult because of structural inertia, defined as a persistent organizational resistance to change in organizational structures and culture (Hannan & Freeman, 1984; Leonard-Barton, 1992; Haveman, 1992; Hannan, Pólos, Carroll, 2003; 2004). As a result of structural inertia, the fit between a firm’s internal and external structures and environmental demands may erode over time and hamper the firm’s survival chances, especially when the environment changes fast (Carroll et al. 1996; Sørensen & Stuart, 2000).

Organizations that pursue exploration may significantly mitigate effects of structural inertia by developing capabilities that allow them to carry out technological and organizational changes to improve their alignment with the shifting environment (March, 1991; Isobe, Makino & Montgomery, 2004; Quintana & Benavides 2008; Ming, 2010). Unfortunately, many firms prefer to focus on exploitation at the expense of exploration because of the inherent trade-offs between stability of exploitation outcomes and uncertain adaptability of exploration activities (Beckman, 2006; O’Reilly & Tushman, 2008; Uotila et al., 2009; Ming, 2010). For example, top management teams tend to develop internal focus and emphasize exploitation at the expense of exploration (Hambrick, Finkelstein & Mooney, 2005; O’Reilly & Tushman, 2008). They prefer to avoid uncertain and distant returns and thus are less likely to search for new routines while continuously improving old ones (Nelson & Winter, 1982). Old routines of exploitation generate reliable feedback that encourages organizations to further pursue exploitation (Lavie et al., 2010). While successful exploitation improves the efficiency of existing capabilities, it
limits the search for new capabilities and may lead to a “competence trap” when managers overestimate the returns of exploitation over the costs of exploration (Levinthal & March, 1993).

Thus, very often a firm’s adaptation to the current environment is attempted through exploitation at the expense of exploration (Lavie et al., 2010). Although exploitation brings stability in an organization, it also leads to increasing structural inertia which prevents the firm from adjusting to changing environmental demands (Hannan & Freeman, 1984; Sørensen & Stuart, 2000). Organizations have to pursue exploration to mitigate structural inertia (March, 1991; Isobe, Makino & Montgomery, 2004). Therefore, in order to achieve a superior alignment with the changing environment, and thus to improve its survival chances, a firm needs to pursue both exploration and exploitation, especially in fast-paced environments (Ming, 2010). Exploration is indispensable for organizational survival in the long run. This discussion allows us to draw the following key assumption: *Exploration increases firm survival in fast-paced environments.*

**HYPOTHESES**

Although the literature suggests that exploration is indispensable for organizational survival in fast-paced environments (March, 1991; Ming, 2010), we believe that the extent of survival benefits from exploration to a firm will depend on characteristics of the firm’s internal and external structures and the firm’s ability to carry out successful organizational change. We propose two interrelated mechanisms that may drive the effects of exploration on firm survival: structural inertia and resource endowment.

The higher the level of a firm’s structural inertia, the less capable is the firm of changing its internal and external structures to meet environmental demands. By engaging in exploration activities, highly inertial organizations have a chance to improve their alignment with the
environment over time and in this way increase their survival chances. By contrast, structurally flexible organizations are likely to have a higher degree of alignment with environmental demands and are more capable of carrying out changes in their structures to maintain this alignment. They derive less dramatic benefits from engaging in exploration. Therefore, it is reasonable to argue that exploration will have a greater beneficial effect on survival of more inertial organizations than on that of less inertial firms.

As prior research has emphasized, exploration is a highly uncertain activity (March, 1991; O’Reilly & Tushman, 2008; Uotila et al., 2009). While potential pay-offs can be great, potential risks are also substantial and costly. Firms with abundant resources can fair reasonably well through exploration even if their efforts lead to a dead end. They also have the luxury of waiting for exploration to pay off even if it takes significant time. The situation is very different for firms with limited resources. Either exploration that failed or exploration that takes too long to generate payoffs may exhaust their resource supply and lead to their organizational death. Therefore, we suggest that firms with greater resource endowment will derive more survival benefits from exploration than firms with poor resource endowment.

Previous research showed that firms of different age, size, entry mode, and product scope differ dramatically in their internal and external structures and resource endowment (Hannan et al., 1998; Carroll & Hannan, 2000; Helfat & Lieberman, 2002; Carroll & Khessina, 2005; Sorenson, 2006; Hannan, et al. 2007; McKendrick & Wade, 2010). We use these organizational dimensions to predict what types of firms are likely to derive greater benefits from exploration.

**Exploration and Firm Size**

Large organizations have complex structures of internal production and employment and of relationships with external actors (Chandler, 1990; Barnett & McKendrick, 2004; Hannan, et
Structural complexity increases the probability that large firms will fail to carry out a planned organizational change successfully (Hannan & Freeman, 1984; Haveman, 1993; Ranger-Moore, 1997; Barnett & Freeman, 2001). This happens because structural complexity makes it difficult to foresee unintended consequences of change and makes the implementation of organizational changes hazardous (Barnett & Carroll, 1995; Carroll & Teo, 1996; Hannan, et al., 2003; 2007). Thus, large organizations tend to be more inertial and, as a result, tend to become misaligned with a changing environment at a faster rate than smaller firms. Therefore, large organizations have a higher need than smaller firms to engage in exploration to mitigate their structural inertia and to improve their fit with the changing environment.

Large organizations tend to possess more slack resources than smaller firms that they can devote to exploration activities (Cohen, 1995; Freeman & Soete, 1999; Beckman, Haunschild & Philips, 2004; Greve, 2007; Bercovitz & Mitchell, 2007; McKendrick & Wade, 2010). If exploration fails, large organizations have resources to live through tough times, whereas small firms with exhausted resources are likely to fail in a similar situation (Carroll & Hannan, 2000).

To summarize, large organizations have a greater need to pursue exploration and they have more resources than smaller firms to do so. They also have resources to fair through failed exploration attempts. Ironically, large organizations often tend to pursue exploitation at the expanse of exploration (Rothaermel & Deed, 2004; Wang, 2009). However, if large organizations do manage to engage in exploration (Sidhu, Volberda, & Commandeur, 2004) they will derive greater survival benefits than exploring smaller firms. Thus, we predict the following:

**Hypothesis 1:** The effect of exploration on organizational survival is more beneficial for large firms than smaller firms.
Exploration and Firm Age

As firms age, they experience structural and cultural changes. Young organizations tend to be simple in their internal and external structures, because they usually start small (Stinchcombe, 1965; Blau, 1970). As organizations age, however, they accumulate dysfunctional routines and structures (e.g., political factions), that is, they become a subject to the liability-of-senselessness (Barron, West & Hannan, 1994). Furthermore, as organizations age and grow, they become more complex and rigid, and fall a subject to the liability-of-obsolescence (Ranger-Moore, 1997). Both the liability-of-senselessness and the liability-of-obsolescence increase structural inertia and result in the increasing misalignment of older firms with their changing environments (Hannan, 1998; Hannan, et al., 2007). Therefore, old firms need more than younger organizations to engage in exploration to mitigate their increasing structural inertia and improve the alignment with the environment.

Additionally, old firms tend to have more resources than younger companies (Penrose, 1959) that can buffer them if their exploration efforts fail (Lavie, et al., 2010). Hence, survival chances of old firms should benefit more from exploration activities than those of younger organizations.

As in case of large organizations, research suggests that old firms prefer exploitation to exploration (Rothaermel & Deeds, 2004). However, if they manage to overcome this bias they should benefit more from exploration than younger companies. Thus, we predict the following:

**Hypothesis 2**: The effect of exploration on organizational survival is more beneficial for old firms than younger firms.

Exploration and Firm Entry Mode

Entry mode describes the way a firm enters a focal industry. A firm may enter *de novo,*
as an entrepreneurial start-up, having no previous business existence of any kind. Alternatively, a firm can be an existing producer elsewhere and diversify into a focal market as a *de alio* organization (Carroll *et al.*, 1996; Helfat & Lieberman, 2002). At the time of entry, *de novo* (an entrepreneurial start-up) and *de alio* (an entrant from another industry) firms differ in initial resource endowment and previous experience (Carroll & Khessina, 2005). *De alio* entrants start with well-developed capabilities and abundant resources that they draw from their parent companies and, thus, are likely to have a significant advantage in performance and survival over *de novo* firms that lack both resources and developed capabilities (Carroll *et al.*, 1996).

However, *de novo* firms are more structurally flexible than *de alio* companies, as they may choose which capabilities to cultivate (Khessina & Carroll, 2008). Consequently, if the environment changes fast enough, *de novo* firms tend to achieve a better alignment with its demands than *de alio* organizations (Carroll *et al.*, 1996; Ganco & Agarwal, 2009).

Since *de alio* firms tend to have an inferior fit with the environment they are in a greater need for exploration than *de novo* organizations. Moreover, they have resources both to invest into exploration activities and to buffer exploration failures. As a result, exploration should contribute more to the survival of *de alio* than *de novo* firms:

**Hypothesis 3**: The effect of exploration on organizational survival is more beneficial for *de alio* firms than *de novo* firms.

**Exploration and Firm Product Scope**

Whether a firm has a narrow or a broad product scope affects its internal and external structures (Sorenson, 2000; Khessina, 2006). Firms with a broad product scope (i.e., with many different products in a portfolio) tend to be more structurally complex than firms with a narrower product scope (Lubben, 1988; Dowell & Swaminathan, 2000; Sorenson *et al.*, 2006).
Specifically, high differentiation to produce a variety of products requires a high level of coordination (Lawrence & Lorsch, 1967) which contributes to internal structural complexity and, thus increases inertia. Firms with multiple product lines have to deal with diverse suppliers and buyers (Kekre, 1987), which contributes to external structural complexity and further amplifies inertia.

In order to increase the alignment with the changing environment, firms with a broad product scope need to engage in exploration. Moreover, they have resources to mitigate potential exploration failures (Sorenson et al., 2006). Therefore, we predict that such firms will derive greater survival benefits from exploration than firms with a narrow product scope:

**Hypothesis 4:** The impact of exploration on organizational survival is more beneficial for firms with a broad product scope than firms with a narrower product scope.

**METHODS**

**Research Setting of the Worldwide Optical Library Market**

We test our hypotheses on the population of all producers that ever participated in the worldwide optical library market from 1990 through 1998. The optical library industry is an appropriate setting for investigating the effects of exploration on organizational survival for several reasons. First, the optical library industry has experienced high rates of innovation that put demands on producers to explore. Second, the data on this industry cover every firm during 1990 to 1998, making it possible to avoid sample selection bias. Third, organizational diversity (*de novo* and *de alio*, large and small, young and old, etc.) of producers in the optical library industry makes it an appropriate setting for testing hypotheses about varying effects of exploration on firms of a different type. Finally, the optical library industry is worldwide, assuring that the results of this study are generalizable beyond the national borders of a particular...
country. Other industries may differ structurally from the optical library market and thus the results of this study should be generalized only to the classes of industries similar to that of the optical library industry.

**Data Sources for Producers of Optical Libraries**

The original data on the optical library producers come from Disk/Trend, Inc., a market research company located in Mountain View, California. Disk/Trend publishes annual reports on different data storage devices, including optical libraries. The first Disk/Trend report on optical libraries was published in 1990.

**Background on Optical Libraries**

The key product of this industry is an optical library, also known as an optical jukebox and an optical tower. An optical library is a subsystem in a UNIX-based image retrieval application. The primary designation of an optical library is storage and retrieval of massive amounts of data. It is used in high-capacity archive storage environments, such as imaging, medical, and video for record retention, backup systems, desktop publishing and the like. An optical library has several advantages compared to other random access removable media storage solutions such as hard disk drives. It has a larger capacity and a lower cost per megabyte. It holds the longest archive life of any media: up to 100 years. In addition, it provides reliable and stable storage.

Three major technological components of an optical library are (1) optical disk drives and disks (media), (2) robotics for picking, loading, unloading, and re-filing media units into optical disk drives, and (3) software to control and link multiple optical disk drives and libraries (Spenser, 1992).

Optical disk drives in a modern optical library are compatible with a variety of different
formats, such as CD-ROM, CD-R, DVD-ROM, DVD-R, DVD-RAM, and Blu-ray. Usually the number of disks in an optical library exceeds the number of drives. This results in the physical exchange of the media whenever the file is accessed from an unloaded disk. This process affects time performance of the library. High-performance library drives minimize spin-up, load and unload times. One optical library may contain up to 2,000 drives with capacity ranging from 650 MG to 50GB per disk. The overall capacity of an optical library ranges from 35TB to 75TB.

The loading and writing/reading technologies have developed with the enhancement of optical disk drive technology. As the need for storage capacity increased, producers offered multiple libraries tied by networks. Data transfer rates, which represent how fast an optical library can write or read a disk, have become important. Data caching technology contributed to increase in data transfer rates. The design of the tower also influences data transfer rates and has been enhanced to keep up with the increasing capacity of towers and the increasing speed of optical disk drives.

A sophisticated software design is required to integrate a library device into a computer system. Such software helps to manage backup, archival, and disaster recovery. It is referred to as data storage software, infrastructure software, network storage software, or simply storage software (Internet.com, 2006). This software includes a database that keeps track of the files on each of the disks as well as software for the disk drive itself (Disk/Trend, 1998).

An optical library is a mixture of diverse technologies, such as loading robotics, writing/reading disk drive technology, media, and software technology. The rapid advance of disk drive technology went together with the swift changes in other technologies and forced firms to explore new avenues while enhancing the current technology. Therefore, the optical library industry is an appropriate setting for investigating the impact of exploration on survival.
Operationalization of Variables

Starting events of production. We defined a firm’s entry into the optical library industry as occurring when the firm shipped its first optical library product to the customer market. The Disk/Trend report provides information on the first shipment in varying degrees of precision. It gives some dates with precision to the month, others with precision to the quarter, and still others with precision to the year. To make the analysis tractable, all the information about timing was converted to decimal years. Dates given to the month were coded as occurring at the beginning of the month. Following Petersen’s (1991) recommendations for dealing with time aggregation, dates given to only the quarter (to the year) were coded as occurring at the midpoint of the quarter (at the midpoint of the year).

Ending events of production. We defined a firm’s exit from the optical library industry as occurring when the firm stopped shipping its optical libraries to the customer market. The Disk/Trend report does not provide exact information on a product’s last customer shipment. The report comes out in the third quarter of each year and covers firms and products for the current year. Based on this information, we assume that the last shipment of the product happens in the third quarter of the year the product was last mentioned in a Disk/Trend report and coded a firm’s exit as occurring at the midpoint of the third quarter of the year the firm shipped its last optical library product.

Demographics of Optical Library Firms

From 1990 to 1998, ninety nine firms entered the worldwide optical library industry, and thirty two firms exited. The data include 395 firm-year observations. Among ninety nine firms, fifteen firms were de novo and eighty four firms were de alio. Companies were located in many different countries, such as Canada, France, Germany, Israel, Japan, Netherlands,
Singapore, South Korea, Spain, Sweden, Taiwan, United Kingdom, and the United States, of which the U.S. and Japan hosted 73% of all producers.

**Dependent variable.** The ‘‘dependent variable’’ in this study is firm failure in the optical library market. We define firm failure as firm disbanding from the optical library industry. Firm disbanding is considered to happen in year t, if the firm did not ship any optical library product in year t+1 and the exit did not happen by either a merger or acquisition. Since the meaning of mergers and acquisitions is ambiguous – possibly resulting from either firm success or failure – exits by either merger or acquisition are excluded from constructing the dependent variable and treated as non-informatively censored on the right.

**Independent variables.** Unless otherwise noted, all the variables are updated annually.

*Exploration score.* There is a great variety of exploration and exploitation measures in the literature. Scholars used objective measures based on firms’ patents (Rosenkopf & Nerkar, 2001; Katila & Ahuja, 2002) and firms’ products based on new technology (Ming, 2010). Scholars also used subjective measures based on managers’ self-reported data (Bierly & Chakrabarti, 1996; McGrath, 2001; He & Wong, 2004; Jansen *et al.*, 2006). These operationalizations frequently lack generalizability and applicability outside their respective contexts. Furthermore, it is often unclear whether such operationalizations are consistent with the conceptual definitions of exploration and exploitation (Gupta, Smith & Shalley, 2006).

To mitigate these concerns, we adopt a method introduced by Uotila *et al.* (2009). They applied a content analysis of mass media articles about firms to quantify firm exploration and exploitation activities. They developed measures that “(1) cover a broad scope of corporate actions, (2) are available for a large number of companies over an extended period of time, and (3) are applicable across a range of industries” (p.224). Their operational definition of
exploration and exploitation stemmed from March’s original notion. Exploration was defined as “things captured by terms such as search, variation, risk-taking, experimentation, play, flexibility, discovery, innovation” and exploitation as “refinement, choice, production, efficiency, selection, implementation, execution” (March 1991, p.71).

We generally followed the method developed by Uotila and colleagues to construct the exploration measure. Additionally, we took a few steps to improve the original measure. First, we expanded the sample of news sources to capture exploration in small and medium size firms. In their study, Uotila and colleagues used a sample of 279 large manufacturing firms listed in the Standard & Poor 500 index. They collected data on exploration in Reuters News, a major news source. Since small and medium size firms, that are common in our empirical setting, have much lower visibility than large firms in major news sources, we expanded the number of news sources used for collecting our data. Specifically, we looked at all publications available in the Factiva database.

Second, we were careful to avoid a news coverage bias. We limited our population of Factiva news sources to those the coverage for which was available for the entirety of our observation period of 1990-1998 and excluded those publications that were in existence for only a fraction of this period. For example, *Electronics Times* was published during the 1985-2002 period and, therefore, was included in the population of our sources of news articles. *CD-ROM World* was published in 1989 -1995, and therefore we excluded it from our news data sources. Out of 180 news sources, initially identified in Factiva, we selected 103 publications that fully covered the period from 1990 to 1998.

Third, although the measure of Uotila and colleagues is highly generalizable across industries, it may require a modification when applied to a specific industry. The search terms
used for generating the exploration and exploitation measures may have an unintended meaning in certain industries. For example, in our empirical setting of the optical library market, search words “search” and “play” may have meanings proposed by March, such as search for a new solution and play with new combinations. However, more often than not these two words have meanings that have no relevance to exploration, but rather imply functions and activities specific to optical libraries. “Search” often means search for a specific piece of data in the optical library. “Play” frequently means a read function executed by optical library drives. Therefore, we excluded terms “play” and “search” from the set of word roots we used to generate the exploration data.

Adjusting the method of Uotila et al. to our empirical setting, we used Factiva database to collect textual data in the form of all news articles published in media outlets and newswire that fully covered the years from 1990 to 1998 and mentioned any optical library producer in our dataset from 1990 to 1998. A total number of 9,317 news documents were collected.

We then conducted a content analysis of collected news documents using software package CONCORDANCE. The individual firm data was collected by year. A firm’s exploration was captured by the words and word roots such as explor*, variation*, risk*, experiment*, flexib*, discover*, innovat* (The wildcard “*” can represent any characters) mentioned in concurrence with the optical library producer. We also created a firm exploitation measure for the validity and reliability tests that we report in the Appendix. Firm exploitation was captured by the words and word roots such as exploit*, refine*, choice*, production*, efficien*, select*, implement*, execut*.

Diversified firms participate in multiple industries and may involve in exploration activities in different industries to a different extent. The search words optical, CD or DVD
were combined with the above root words and companies’ names to find words that indicate firm exploration orientation specifically in the optical library industry.

As the next step, we identified inappropriate forms of words, such as executive(s) for execut*, because they do not represent exploration or exploration activities. These words were excluded from the calculation of the exploration measure.

We used the collected company-year data on mentions of exploration activities of firms in the optical library market to create the exploration (and exploitation) score. The exploration score of each firm in a given year was calculated by summing the number of words that contained any of the seven word roots of exploration. From 1990 to 1998, the total number of words associated with exploitation (8,925 words) surpassed the total number of words associated with exploration (4,453 words). While exploitation is more prevalent in the optical library industry, the relative portion of exploration to the sum of exploration and exploitation activities increased over time (0.33 to 0.38).

We did not find any media mentions of thirty two firms in our database, most of which were small non-U.S. companies. One should keep this in mind when interpreting our findings with respect to small foreign firms.

We conducted a series of validity and reliability tests of the data collected from news sources for the construction of the exploration variable. For example, we compared our measure of exploration based on news data with a popular exploration measure based on firm patents and found high convergence validity between the two measures.² The detailed information about this and other validity and reliability tests is reported in the Appendix. These tests increase the confidence in our exploration measure.

²Because only 28 out of 99 firms in our population have patents in technological areas related to optical libraries, the measure of exploration based on patents would not be appropriate to use in our empirical setting.
Content analysis produced the data that allowed us to calculate how many times in a given year a specific firm was mentioned in mass media in association with exploration activities. We used these raw data to create time-variant firm-specific variables of exploration score.

The literature agrees that effects of exploration on a firm occur over time (March, 1991, Ming, 2010). It is unrealistic to assume that firm survival in a given year is affected by exploration that took place only during that year or during the year prior. In fact, exploration may take many years before its payoffs materialize and have any visible impact on firm performance and survival. To account for this influence we created the exploration score based on the cumulative count of media mentions of a firm in association with exploration activities, so that exploration score in a given year is a sum of media counts in this year and counts in the prior years of firm existence. We reason that the cumulative exploration score provides a more accurate measure of a firm’s long-term involvement in exploration and its effect on survival.

To test our hypotheses that effects of exploration on firm survival differ by a firm type, we created four variables that serve as a proxy for different types of organizations.

*Firm size.* We constructed a measure of the *firm size* as a scale of operations, specifically, as a firm’s annual revenue in millions of U.S. dollars from its sale of optical libraries. Disk/Trend provides specific sales data only for the major 10-20 producers in the market. For non-major producers, Disk/Trend does not publish firm-specific revenue figures. However, Disk/Trend records the annual aggregate revenue of these non-major, smaller producers based on their geographic location: companies based in the United States and those not in the United States. We imputed the annual revenue for each smaller producer in non-US and US categories by dividing the total revenue of non-major producers in a category by the number of non-major producers in that category. The measure is logged to reduce skewness.
Firm tenure. We created the variable firm tenure measured as the number of years a firm has operated in the optical library industry to test how exploration affects survival of firms of different age.

Firm entry mode. This variable takes the value of one if a firm entered the optical library industry as an entrepreneurial start-up, and the value of zero if a firm diversified into this industry from another market. This variable is time-invariant.

Firm product scope. We constructed the variable that measures the scope of a firm’s product portfolio by counting the number of unique product models that a firm ships to the market in a given year.

Organizational controls. Organizational characteristics other than firm size, tenure, entry mode, and product scope may affect firm survival chances. Several organizational controls are used to account for these influences. Unless otherwise noted, all controls are updated annually.

Firm headquarters. U.S. firms dominated the optical library market during the observation period. Japanese firms were dominant in the non-U.S. market of the optical library industry. To control for the market prevalence of American and Japanese firms we created three dummy variables. U.S. HQ dummy takes the value of one if a firm had headquarters in the U.S, and the value of zero if otherwise. Japan HQ dummy takes the value of one if a firm had headquarters in Japan and the value of zero if otherwise. Other countries HQ dummy takes a value of one if a firm had headquarters in countries other than the U.S. and Japan and the value of zero if otherwise, and serves as an omitted category in analyses.

Joint venture. Joint ventures may have a different survival dynamics because they rely on resources and good will of multiple parties. To control for this influence we created a
dummy variable that takes the value of one if a company was a joint venture and the value of zero if otherwise.

*Firm experience in ODD technology.* An optical disk drive is one of the key components in optical libraries. A quarter of producers of optical libraries made their own optical disk drives (25 out of 99 firms), while the others had to buy them from manufacturers. The experience in in-house production of the key optical library component may have a beneficial effect on firm survival. To control for this influence, we created a variable that measures the number of years a firm has been making optical disk drives by a given year.

*Firm number of patents.* A firm’s technological capabilities are partly represented by a firm’s total number of patents (Pandit, Wasley, & Zach, 2009). To control for the influence of firm technological capabilities on its survival, we created a variable that counts the number of patents granted to a firm in a given year.

*Firm number of new products.* New products represent a firm’s ability to commercialize the value of its R&D activities (Katila & Ahuja, 2002) and thus affect firm survival. We created the variable that counts the number of products a firm introduces to a market in a given year to control for this influence.

*Firm age at entry.* In addition to firm tenure in the optical library industry, we created a variable that measures firm age at the time it started shipping optical libraries. This variable controls for the influence of a firm’s experience before its entry into the optical library market. The measure is time-invariant. It is logged to reduce skewness.

*Firm media visibility.* We expect that a firm’s size affects the extent of its media exposure. In turn, this variation in media exposure may influence the firm’s exploration score. As a result, the weight of firm exploration score may vary with firm size. We control for this
variation by adding the variable, firm media visibility, which is a standardized number of news articles published about a firm (Fombrun & Shanley, 1990).

*Left-censored firm.* The first optical library was shipped to the market in 1984. However, the most comprehensive data source that we were able to find started collecting information on optical library producers only in 1990. To control for firms in our database that existed before 1990 we created a dummy *left-censored firm* that takes the value of one if a firm started shipping optical libraries before 1990 and the value of zero if otherwise.

**Industry controls.** Several variables are used to control for industry processes. Unless otherwise noted, all variables are updated annually.

*Industry sales* were measured in millions of U.S. dollars to control for the effects of environmental munificence on firm survival.

*Density all firms.* Empirical studies found a U-shape relationship between firm density and firm mortality rates in a great variety of industries (for a review see Carroll & Hannan, 2000). To take account of this relationship, we created the *density of all firms* and *density of all firms squared.* Density was measured as the number of firms competing in the optical library industry in a given year. Both variables are lagged by one year.

*Density at entry.* High density at the time of a firm’s entry into the market signifies resource scarcity that inhibits organization building and may have a long-term negative effect on survival chances (Carroll & Hannan, 1989). To control for this influence, the variable *density at entry,* which is the number of firms on the market in the year a firm started shipping optical libraries, was created.

*Density of patents in relevant fields.* Patent proliferation in knowledge areas relevant to the optical library market may indicate technological munificence of the market and affect firm
survival. To control for this influence we created a variable that counts the number of patents granted in the computer and optical technologies in a given year.

**DVD technology period.** Optical drives based on DVD technology were introduced to the market in 1996. Many considered DVD technology a threat to the previous CD technology, because it allowed users to store significantly larger amount of data. Firms participating in optical storage markets were affected by this technological shift. To account for the increasing influence of DVD technology over time we created a period variable *DVD threat* that takes a value of zero for years 1990-1995 and a value of one for year 1996, a value of two for year 1997, and a value of three for year 1998.

**OSTA period.** Optical Storage Technology Association (OSTA) is an international trade association that was founded in 1992 to support the use of optical products by promoting compatibility across different products and producers. It had a visibly stimulating effect on the development of optical storage markets. To account for this influence we created a period variable that takes a value of zero for years 1990-1991, the value of one for years 1992-1998.

**Model Specification**

To test the hypotheses that make predictions about the effects of exploration on firm survival, we use continuous-time event-history analysis. We treat a firm as the unit at risk, and the “dependent variable” is the instantaneous rate of a firm’s disbanding defined as:

\[
    r(t) = \lim_{\Delta t \to 0} \frac{\text{Prob}[t < T < t + \Delta t | T > t]}{\Delta t}
\]

where \(T\) is a random variable for the time of the event of interest, \(t\) is the time elapsed since the time a firm entered the optical library industry, and \(\text{Prob(.)}\) the conditional probability that the firm will disband over the interval \([t, t+\Delta t]\) given that the firm was still in existence at time \(t\).
A piecewise exponential function is used to measure variation in the timing of a firm disbanding from the industry, to achieve a flexible specification of organizational age-dependence. A piecewise exponential model splits the time axis into time pieces determined by an analyst (Carroll & Hannan, 2000: 136-138). After examining life tables and exploring estimates of a variety of choices of the breakpoints, we decided to break the duration scale in years at 1.0, 2.0, 3.0, 6.0 and 7.0.

Since observations within specific firms are not necessarily independent, we use Huber/White/sandwich estimator of variance with cluster option that relaxes the assumption of independence to calculate robust standard errors in firm exit models (Williams, 2000).

To test our hypotheses, we specify a firm’s disbanding rate \( r(u,t) \) as a function of firm tenure in the industry \( u \), firm exploration score \( E \), the vector of covariates measuring firm characteristics \( F \), the interactions between firm exploration score and firm characteristics \( EF \), and the other measured covariates \( X \). The general class of models we estimate has the form:

\[
\ln r(u,t) = E_{it} + \sum \phi_k F_{kit} + \sum \delta_k E_{it} F_{kit} + \sum \gamma X_{nit},
\]

where \( E_{it} \) denotes an exploration score for firm \( i \) at time \( t \), the \( k \) covariates measuring firm characteristics are summarized in \( F_{kit} \), and \( X_{nit} \) summarizes all other time-varying covariates.

To test the hypotheses we estimated models with the method of maximum likelihood as implemented with a user-defined routine in STATA (Sørensen, 1999). To estimate hazard rate models with time-varying covariates, we constructed a split-spell data file by breaking observed durations in year-long periods with the values of covariates undated every year.

**RESULTS**
Table 1 provides descriptive statistics of the split-spell file used for the event history analysis. The file contains multiple spells for each firm, so it does not always intuitively reflect the experiences of firms on the market.

[Insert Table 1 here]

Table 2 presents estimates from piecewise exponential models of effects of firm exploration score on firm disbanding rates. Negative coefficients indicate firms’ lower disbanding rates, i.e., higher survival rates. Positive coefficients indicate the opposite. Model 2.1 is a baseline model that includes all the control variables and firm exploration score. The controls show common effects. While the exploration score variable has an expected negative effect on firm disbanding, it is not significant. Since we predict the effect of exploration to be different for different types of firms, we believe that the predicted differences may drive the insignificance of the overall main effect of exploration.

[Insert Table 2 here]

Models 2.2-2.6 are designed to test our hypotheses. They include interaction terms of firm exploration score with different organizational characteristics. Model 2.2 shows the effect of the interaction between firm exploration score and firm size. As predicted, the interaction coefficient is significant and negative: Exploration decreases firm disbanding more (i.e., increase firm survival more), as firms get larger. This result suggests that the beneficial effect of exploration on organizational survival is greater for larger firms. Thus, Hypothesis 1 is supported.

Model 2.3 shows the effects of the interactions between a firm’s tenure in the optical library industry and its exploration score. None the interaction terms of exploration score with

---

3 In the literature on ambidexterity, the combination of exploitation and exploration may have a negative effect on firm mortality rather than either exploitation or exploration alone (Ming, 2010). In supplementary analysis, we found that the multiplication of exploration score and exploitation score has a significant negative effect on firm disbanding.
tenure pieces is significant. We think that the observation window of our empirical setting is too short to observe the interaction effect between firm exploration and its tenure in the optical library industry. Thus, Hypothesis 2 is not supported.

In Model 2.4 we test for the interaction between firm exploration score and firm entry mode. As predicted, the coefficient is positive and significant. It indicates that the impact of exploration on \textit{de novo} firm survival is less beneficial than on that of \textit{de alio} firms. This finding supports Hypothesis 3.

In Model 2.5 we add the interaction term between firm exploration score and firm product scope. As predicted, the effect is negative and significant indicating that exploration is more survival enhancing for firms with broader product portfolios. This result supports Hypothesis 4.

Model 2.6 includes interaction terms of firm exploration with firm size, firm tenure, firm entry mode and firm product portfolio at once. The results are similar to those in Models 2.2-2.5 with one exception. The previously insignificant interactions between the exploration score and firm tenure pieces are now significant at p>.05 level. They show that the beneficial effect of exploration on firm survival first decreases and then (once a firm has been in the industry for 6 years) increases with firm tenure. This result suggests that the effect of exploration on aging is not linear, as we predicted in Hypotheses 2, but curvilinear. While we did not predict such dependence, this finding is consistent with Sorensen and Stuart’s study (2000) where they showed that firm innovative capabilities have a U-shape relationship with organizational age.

Model 2.6 also confirms the previous results that exploration has greater beneficial effects on survival of larger firms, \textit{de alio} firms and firms with broader product portfolios. It thus provides further support to Hypotheses 1, 3 and 4.
DISCUSSION

Since March (1991) posited the impact of exploration on organizational survival, little research has been done to support this idea empirically (but see Ming, 2010). This paper reveals explicitly the relationship between exploration and organizational survival. More importantly, it shows the exploration is not universally survival enhancing for all types of firms. The extent of exploration positive impact on survival varies across different organizational types. Specifically, we found that although exploration enhances organizational survival overall, this effect significantly varies across firms of different size, entry mode, and product scope.

According to organizational ecologists, large firms are exposed to strong structural inertia that may erode their alignment with environmental demands (Hannan & Freeman, 1984; Sørensen & Stuart, 2000; Hannan et al., 2007). Firms with a broad product scope also tend to be complex and, as a result, inertial (Sorenson, et al., 2006). De alio firms suffer from greater inertia and potential misalignment with environmental demands as well (Khessina & Carroll, 2008). Exploration is more beneficial for large firms, de alio firms and firms with broad product scope than for smaller, de novo and narrower scope organizations, because they are in a greater need of exploration to improve their alignment with the environment and they have slack resources that they can use to fair through a potential exploration failure.

It is ironic, that firms that have a greater need to engage in exploration to enhance their viability, such as large firms, firms with broad product scope, and de alio firms, also tend to be those that prefer to focus on exploitation at the expense of exploration (Rothaermel & Deed, 2004; Wang, 2009). Those of these firms that do manage to pursue exploration stand to derive, however, great survival benefits. Managers should keep this in mind when deciding on their new exploration and exploitation strategies.
This study makes several important contributions. First, it contributes to the exploitation and exploration literature. It adds empirical evidence that exploration has a beneficial impact on organizational survival. Although March (1991)’s work originated from the speculation of the relationship between the balance of exploitation and exploration and organizational competitiveness and survival, few studies paid attention to the aspect of survival (but see Dowell & Swaminathan, 2006; Ming, 2010). Additionally and more importantly, this paper explicitly theorizes about the varying effects of exploration on survival chances of different types of firms. It is also the first to empirically reveal how organizational characteristics mediate the effect of exploration on firm survival.

Second, the study contributes to organizational ecology literature. It shows that firm involvement in exploration is an important predictor of its survival and thus can affect the evolutionary dynamics of firms and their industry.

Finally, this study has important strategic implications for managers. It suggests that managers of large firms, de alio firms and firms with broad product scope should give significant weight to exploration when planning for and executing firm innovation strategies.

A limitation of this study is that the impact of exploration on organizational viability may play out differently in industries dramatically different from the optical library market. For example, exploration has less influence on organizational survival in less dynamic and competitive industries. Studies in other industries are necessary to find possible boundary conditions that moderate the relationship between exploration and organizational survival.
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Carroll, G.R., A.C. Teo. 1996. Creative self-destruction among organizations: An empirical study of technical innovation and organizational failure in the American automobile industry,


APPENDIX

Validity and Reliability Tests of the News Data for Exploration and Exploitation Measures

We conducted several validity and reliability tests of the exploration (and exploitation) score measure.

Validity Tests

To establish the convergent validity of the exploration and exploitation scores, we measured exploration and exploitation using patent data. The exploration and exploitation scores using patent data were calculated using the approach of Wang and Li (2008). The exploration score in a given year was calculated by the number of citations to patents that were outside of the firm’s main class of patented technology, whereas the exploitation score in a given year was calculated by the number of citations to patents that were within the main class of the firm’s patented technology. The firm’s main class of patented technology was determined by the class of patents that the firm applied for before a given year. We computed the correlation between the measures of exploration and exploitation based on the content analysis and the measures of exploration and exploitation based on the patent data by firm-year (28 out of the 99 firms have patents in the optical disk industry). The correlation between the exploration score generated by the “patent” method and the exploration score generated by the “content analysis” method used in this study is 0.77 (p=0.00) and the correlation between “patent” exploitation scores and “content analysis” exploitation score is 0.77 (p=0.00). These correlations suggest a high level of convergent validity of our measure.

To assess the content validity of the exploration and exploitation measures, we sampled from our population fourteen firms that were in existence in 1998. The sample consisted of five public firms and nine private firms to reflect the ratio of public to private firms in the population.
Two independent coders read all news in the Factiva database about the fourteen firms selected for the validity test to determine whether these news items captured exploitation and exploration activities based on the concepts of exploration and exploitation that March (1991) proposed. If a coder made a decision that a certain news article did not represent exploration and exploitation activities, the entire news article was removed from the data generated for content analysis. The correlation between this manual classification and the automated classification was calculated. The correlation for the exploration classifications was 0.93 (p=0.00) and for exploitation classifications was 0.67 (p=0.01). This high correlation (especially for the exploration measure) provides evidence of validity for the automated content analysis.

**Reliability Test**

Fifteen word roots were used to identify exploration (seven word roots: explor*, variation*, risk*, experiment*, flexib*, discover*, innovat*) and exploitation (eight word roots: exploit*, refine*, choice*, production*, efficien*, select*, implement*, execut*) in the news documents collected.

The portion of individual exploration (exploitation) word roots out of the total number of word roots that capture exploration (exploitation) during the observation period was calculated. For example, among the seven word roots that capture exploration, “innovation” was the most frequent and included 25% of generated word roots that are associated with exploration. “Flexibility” (23%), “risk” (21%), “discover” (10%) and “experiment” (10%) followed “innovation”. The rest of the exploration word roots comprised less than 10% each.

Among the eight exploitation word roots, “production” was the most frequent word and included about 59% of all exploitation words. “Select (13%)”, “implement (11%)” and “choice (10%)” followed “production”. The rest of the word roots made up less than 10% each.
A single influential word such as “innovation” and “production” can have spurious effects on results. For example, the word root “production” accounted for 59% of the eight word roots for exploitation and “innovation” accounted for 25% of the seven word roots for exploration. If such influential words have spurious effects on results, the exploration and exploitation scores using the multiple word roots do not measure exploration and exploitation activities consistently. To deal with this potential issue, alternative measures of exploration and exploitation scores were calculated by excluding each word root from a content analysis. The correlations among the full and seven partial exploration scores are between 0.97 to 0.99. The correlations among the full and eight partial exploitation scores are between 0.85 to 0.99. The results based on these partial measures were consistent with results based on full measures and supported the reliability of the exploration measure reported in the paper.
Table 1. Descriptive statistics for optical libraries producers: Split-spell file

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs. / Spells</th>
<th>Mean</th>
<th>St.Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm cumulative exploration score (t)</td>
<td>395</td>
<td>45.97</td>
<td>107.5</td>
<td>0</td>
<td>876</td>
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<tr>
<td>Density all firms (t-1)</td>
<td>313</td>
<td>44.98</td>
<td>17.81</td>
<td>17</td>
<td>72</td>
</tr>
<tr>
<td>Density² all firms (t-1)</td>
<td>313</td>
<td>2339.28</td>
<td>1695.07</td>
<td>289</td>
<td>5184</td>
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<tr>
<td>Firm density at entry (u₀)</td>
<td>395</td>
<td>33.42</td>
<td>20.43</td>
<td>2</td>
<td>72</td>
</tr>
<tr>
<td>WW industry sales [in mln. U.S.$] (t)</td>
<td>395</td>
<td>380.54</td>
<td>134.77</td>
<td>106.2</td>
<td>526.2</td>
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<tr>
<td>Density of patents in relevant fields (t)</td>
<td>395</td>
<td>2300.59</td>
<td>905.46</td>
<td>289</td>
<td>3954</td>
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<tr>
<td>Left censored firm dummy = 1</td>
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<td>0.30</td>
<td>0.46</td>
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<td>1</td>
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<tr>
<td>DVD technology period (t)</td>
<td>395</td>
<td>1.020</td>
<td>1.168</td>
<td>0</td>
<td>3</td>
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<tr>
<td>OSTA period (t)</td>
<td>395</td>
<td>0.873</td>
<td>0.333</td>
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<td>1</td>
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<tr>
<td>Firm HQ dummy: Japan = 1</td>
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<td>1</td>
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<td>Firm HQ dummy: US = 1</td>
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<td>0.42</td>
<td>0.49</td>
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<td>1</td>
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<td>Joint venture dummy = 1</td>
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<td>Ln firm number of patents (t)</td>
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<td>Firm experience in ODD technology (t)</td>
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<td>2.56</td>
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<td>Firm number of new products (t)</td>
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<td>Ln firm age at entry (u₀)</td>
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<td>Ln firm size [in million U.S.$] (t)</td>
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<td>1.22</td>
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<td>Firm product scope (t)</td>
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<td>0.14</td>
<td>0.35</td>
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<td>Firm media visibility (t)</td>
<td>395</td>
<td>0</td>
<td>1</td>
<td>-0.50</td>
<td>7.71</td>
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Table 2. Piecewise exponential models of effects of firm exploration score on firm disbanding rates (Robust standard errors shown in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model (2.1)</th>
<th>Model (2.2)</th>
<th>Model (2.3)</th>
<th>Model (2.4)</th>
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<td>(7.627)</td>
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<td>(7.541)</td>
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<td>1.168**</td>
<td>1.227*</td>
<td>1.115*</td>
<td>1.341*</td>
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<td>(0.457)</td>
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<td>-0.014**</td>
<td>-0.015*</td>
<td>-0.013*</td>
<td>-0.017*</td>
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<tr>
<td></td>
<td>(0.006)</td>
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<td>(0.006)</td>
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<td>(0.008)</td>
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<td>Firm density at entry (u_e)</td>
<td>0.166*</td>
<td>0.166*</td>
<td>0.161*</td>
<td>0.180*</td>
<td>0.164**</td>
<td>0.217*</td>
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<tr>
<td></td>
<td>(0.067)</td>
<td>(0.068)</td>
<td>(0.067)</td>
<td>(0.072)</td>
<td>(0.063)</td>
<td>(0.107)</td>
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<td>-0.023</td>
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<td>DVD technology period (t)</td>
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<td>3.206</td>
<td>2.096</td>
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<td>4.647</td>
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<td>(2.374)</td>
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<td>(2.943)</td>
<td>(3.234)</td>
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<td>-1.891</td>
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<td>(1.264)</td>
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<td>Left-censored firm dummy = 1</td>
<td>0.669</td>
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<td>0.155</td>
<td>-0.578</td>
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<td>(1.121)</td>
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<td>(1.104)</td>
<td>(1.075)</td>
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<td>Firm HQ dummy: Japan = 1</td>
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<td>0.088</td>
<td>-0.186</td>
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<td>Firm HQ dummy: US = 1</td>
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<td>-0.867</td>
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<td>(1.081)</td>
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<td>(1.065)</td>
<td>(1.114)</td>
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<td>Joint venture dummy = 1</td>
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<td>-1.352</td>
<td>-1.212</td>
<td>-1.188</td>
<td>-2.139</td>
<td>-1.606</td>
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<td>(1.368)</td>
<td>(1.316)</td>
<td>(1.192)</td>
<td>(1.000)</td>
<td>(2.614)</td>
<td>(1.623)</td>
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<td>Firm experience in ODD technology (t)</td>
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<td>-0.038</td>
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<td>(0.073)</td>
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<td>(0.076)</td>
<td>(0.082)</td>
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<td>Ln firm number of patents (t)</td>
<td>-0.056</td>
<td>-0.125</td>
<td>0.026</td>
<td>0.012</td>
<td>-0.021</td>
<td>0.021</td>
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<td>(0.223)</td>
<td>(0.241)</td>
<td>(0.304)</td>
<td>(0.239)</td>
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<tr>
<td>Firm number of new products (t)</td>
<td>-0.195</td>
<td>-0.213</td>
<td>-0.219</td>
<td>-0.191</td>
<td>-0.094</td>
<td>-0.098</td>
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<td>(0.387)</td>
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<td>(0.412)</td>
<td>(0.388)</td>
<td>(0.381)</td>
<td>(0.475)</td>
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<tr>
<td>Ln Firm age at entry (u&lt;sub&gt;0&lt;/sub&gt;)</td>
<td>-0.229</td>
<td>-0.319</td>
<td>-0.229</td>
<td>-0.249</td>
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<td>(0.298)</td>
<td>(0.320)</td>
<td>(0.306)</td>
<td>(0.291)</td>
<td>(0.320)</td>
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<tr>
<td>Ln firm size [in million U.S. $] (t)</td>
<td>-1.091*</td>
<td>-0.791*</td>
<td>-0.973**</td>
<td>-1.131*</td>
<td>-0.992*</td>
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<td>(0.428)</td>
<td>(0.401)</td>
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<td>(0.442)</td>
<td>(0.413)</td>
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<td>Firm product scope (t)</td>
<td>-0.324*</td>
<td>-0.356*</td>
<td>-0.312*</td>
<td>-0.363*</td>
<td>-0.206</td>
<td>-0.227</td>
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<td>(0.129)</td>
<td>(0.146)</td>
<td>(0.126)</td>
<td>(0.148)</td>
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<td>Firm entry mode dummy: de novo = 1</td>
<td>-0.207</td>
<td>-0.374</td>
<td>-0.260</td>
<td>-1.455</td>
<td>-0.200</td>
<td>-2.222</td>
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<td>(1.007)</td>
<td>(1.084)</td>
<td>(1.068)</td>
<td>(1.370)</td>
<td>(1.045)</td>
<td>(1.997)</td>
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<tr>
<td>Firm media visibility (t)</td>
<td>1.227</td>
<td>2.035*</td>
<td>0.922</td>
<td>0.916</td>
<td>1.918</td>
<td>2.772</td>
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<td>(0.668)</td>
<td>(0.996)</td>
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<td>(0.925)</td>
<td>(1.135)</td>
<td>(3.299)</td>
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<td>Firm exploration score (t)</td>
<td>-0.013</td>
<td>0.092*</td>
<td>-0.001</td>
<td>-0.017</td>
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<td></td>
<td>(0.011)</td>
<td>(0.046)</td>
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<td>(0.011)</td>
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**Firm exploration score * Firm size**

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<td>Firm exploration score * Firm size</td>
<td>-0.016*</td>
<td>-0.130*</td>
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<td>Firm tenure: 0 ≤ u ≤ 1</td>
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<td></td>
<td>(0.007)</td>
<td>(.057)</td>
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<td>Firm exploration score * Firm tenure: 0 ≤ u ≤ 1</td>
<td>-0.007</td>
<td>0.980*</td>
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<td>(0.017)</td>
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<td>(0.415)</td>
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<td>(0.021)</td>
<td>(0.438)</td>
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<td>Firm exploration score * Firm tenure: 6 ≤ u ≤ 7</td>
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<td>0.998*</td>
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<td>Firm exploration score * Firm tenure: 7 ≤ u</td>
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<td>0.957*</td>
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<td>Firm exploration score * Firm tenure: &gt; 7</td>
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<td>0.159*</td>
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<td>(0.012)</td>
<td>(0.013)</td>
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<td>(d.f.)</td>
<td>(26)</td>
<td>(27)</td>
<td>(31)</td>
<td>(27)</td>
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p* < 0.05, p** < 0.01, p*** < 0.001; two-tailed tests