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# WHEN DOES LACK OF RESOURCES MAKE NEW FIRMS INNOVATIVE?

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**We extend the resource-based perspective to explain innovation in new firms that have yet to develop resources. Using data on firms' efforts to commercialize technological inventions, we tested a model of the environmental conditions under which new firms' lack of resources alternately promotes or constrains innovation. We found that new firm innovation is greater in competitive and small markets, and in environments that do not demand extensive production assets.**

When are new firms innovative? Organizational researchers have long studied this question, but mixed findings have emerged from these studies. Some scholars have suggested that new firms, which cannot use existing firm knowledge (Cohen & Levinthal, 1990) and resources (Teece, 1986), have trouble innovating. However, other authors have argued exactly the opposite: New firms are highly innovative because their innovative efforts do not cannibalize their existing products (Arrow, 1962) or require them to filter new knowledge through organizational routines and structures that are ill-suited to that purpose (Henderson & Clark, 1990).

More recently, researchers have sought to reconcile these conflicting perspectives by focusing on the nature of the new technology, arguing that new firms are better suited to developing radical innovations than incremental ones (Christensen & Bower, 1996; Hamilton & Singh, 1992). Although extremely informative, this approach fails to explain an important empirical phenomenon: Why are new firms better at innovation in some industries than in others?

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Our study seeks to examine the environmental characteristics that give rise to innovation in new firms. Building upon the recommendations of resource-based theorists to consider the relationship between resources and the environmental context in which they are used (Miller & Shamsie, 1996; Priem & Butler, 2001), we propose an environmental contingency approach. New firms are more effective innovators in environments where lack of resources is a benefit, and worse in environments where such a lack is a constraint.

Our approach is valuable in three ways. By showing that the value of resources depends on the environment, our study helps to unravel when resources promote, and when they hinder, innovation. In addition, our study contributes to research on firm resources by considering the case of firms that have not yet developed or acquired those resources. By examining when *not* having resources is valuable, we shed light on the relative contributions that organizational resources make to innovation. Furthermore, by using inventions patented and licensed by the Massachusetts Institute of Technology in 1980–96 as the source for the empirical sample, we were able to examine inventions at risk of commercialization by both new and established firms. Through this approach, we avoided sample selection bias, which often makes it difficult to interpret results on firm newness and innovation (Barnett & Burgelman, 1996).

## THEORETICAL BACKGROUND

### Key Constructs

***Innovation.*** Following prior research, we define innovation as "a process that begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process or service to the marketplace" (Edwards & Gordon, 1984: 1). Innovation begins when a firm chooses an invention for development, with the ultimate goal of introducing it to the market (Kuznets, 1962). This definition is also consistent with Schumpeter's description: "The making of the invention and the carrying out of the corresponding innovation are, economically and sociologically, two entirely different things" (1939: 85).

***Firm newness.*** In contrast with the authors of economic studies that focus on incentives to innovate, and consequently have used time of market entry to conceptualize newness, we examined innovation from the organizational standpoint. Accordingly, we used time of organizational founding to define newness (see also Henderson, 1994; Sørensen & Stuart, 2000). Specifically, we defined new firms as newly founded organizations and established firms, as organizations already in existence. Further, new firms are stand-alone organizations and do not include new in-house manufacturing or marketing units, new divisions of established corporations, or new collaborative manufacturing or marketing units owned by two established firms.

***Environment.*** Prior research suggests that several environmental factors influence the innovation process (Kuznets, 1962; Utterback, 1994). First, the degree of competition influences innovation because firms need to transform new ideas into new products more effectively than competitors. Second, availability of financial resources influences innovation because access to capital allows an innovator to follow the normal path of developing the new product before selling it to others. Third, the manufacturing intensity of the production process influences innovation because information about manufacturing influences product development. Fourth, the size of the market influences innovation because the innovator needs to believe that the market size is sufficient to justify the investment of time and money in the uncertain activity of developing new products in place of investing in other activities.

## Theoretical Development

The resource-based view of the firm seeks to explain how organizations develop and maintain competitive advantage using firm-specific resources and capabilities (Wernerfelt, 1984). According to this perspective, resources are assets or inputs to production that an organization owns or accesses (Helfat & Peteraf, 2003); while capabilities are the ability to use resources to achieve organizational goals (Amit & Schoemaker, 1993; Helfat & Lieberman, 2002). The basic premise is that resources and capabilities increase the efficiency and effectiveness of firms (Barney, 1991).

One central area of recent investigation has been the development of resources to create competitive advantages through innovation (Ahuja & Katila, 2004; Leonard-Barton, 1992). For example, researchers have sought to understand how the (dynamic) capabilities of firms make them effective at the development of new products and processes (Rindova & Kotha, 2001; Smith, Collins, & Clark, 2005). Although this work has focused on explaining why some established firms outperform other established firms (e.g., Miller, 2003), researchers could use this perspective to explain why new firms—firms that do not yet have these resources—are effective at innovation.

A second central area of recent investigation has been the contingent value of resources. According to this view, which builds on the environmental contingency approach in organizational theory (Lawrence & Lorsch, 1967; Pfeffer & Salancik, 1978), firm resources do not exist in isolation, but their value is influenced by the environments in which the firms are found (e.g., Priem & Butler, 2001). For instance, Barney (1991) explained that the environmental context in which an asset is applied will influence whether or not the asset is a resource. Empirical work has confirmed the contingent value of resources on the performance of veterinary practices (Brush & Artz, 1999), on strategic changes in savings and loans institutions (Zajac, Kraatz, & Bresser, 2000), and on the performance of film studios (Miller & Shamsie, 1996). However, none of these studies have examined the contingency perspective in the context of innovation, as is done in this study. Yet for high-technology firms, innovation is one of the main sources of competitive advantage.

Contingency theory has a long tradition of discussing how different dimensions of the external environment interact with organizational attributes. We focus on four dimensions that are especially relevant to innovation: the degree of competition in an environment (Pfeffer & Leblebici, 1973), the availability of financial resources (Pfeffer & Salancik, 1978), manufacturing intensity (Thompson, 1967), and market size (Lawrence & Lorsch, 1967).

# HYPOTHESES

We develop hypotheses about how four environmental dimensions influence the relationship between firm newness and innovation. We propose that lack of resources makes new firms better at innovating in certain environments and worse at innovating in others.

## Competition

Markets differ significantly in the number of competing firms they contain because bandwagon effects, economic factors, and the attractiveness of a market at a given point in time all influence number of competitors. We argue that firm newness operates differently in high-competition than in low-competition markets for three reasons. First, new firms perform better in crowded markets because these markets require greater flexibility to introduce innovations. This is because competition over resources is higher in markets with more firms (Hannan & Freeman, 1984). In such markets, firms that are good at deriving high value from a given amount of resources—that is, firms that use resouces creatively (Starr & MacMillan, 1990)—are likely to be innovative. Prior work shows that new firms tend to use resources creatively because they do not have the specialized structures and routines that often prevent firms from thinking about new uses for existing resources. Instead of following already created routines, many processes in new firms are emergent, yielding innovative solutions (Baker, Miner, & Eesley, 2003). Empirical results support this argument: for instance, Schoonhoven and her colleagues (Schoonhoven, Eisenhardt, & Lyman, 1990) found that new semiconductor firms shipped products faster when they had many competitors, because competition spurred the firms to innovate better. In contrast, when fewer firms operate in a market and, consequently, more resources are available, new firms are less innovative. Under these conditions, instead of flexibility, firms need the routinized capabilities of established firms to help them to acquire and assemble resources—capabilities that new firms have not yet mastered (Bhide, 1992).

Second, new firms perform better under the condition of competitive ambiguity that is present in high-competition markets. Fragmentation resulting from the presence of a large number of firms increases ambiguity about competitive issues such as the positioning of products in a market (Cohen & Klepper, 1992; Sorenson, 2000). New firm managers adapt well to such ambiguity because the absence of existing operations allows them to make changes in positioning without worrying about the effect of such changes on existing customer or supplier relationships. Conversely, when markets have fewer firms, competitive ambiguities are lessened, favoring the more routinized operations of established firms (Katila & Mang, 2003).

Third, new firms are more innovative in markets where diversity in approaches to innovation is high. The variance in approaches to innovation is an increasing function of number of competitors because each firm, with innovation modes and routines specific to its history, is likely to offer a different alternative approach (Dosi, 1988). Because new firms lack routines for innovation, they are disadvantaged in markets where innovation routines are standardized and little room for variation exists. In contrast, new firms perform well in markets that welcome a number of approaches to innovation (Moorman & Miner, 1998). Thus, we propose:

*Hypothesis 1. New firms have a higher rate of innovation in more competitive markets.*

## Financial Resources

New firms often lack sufficient capital to finance innovation. Therefore, they must raise resources from external sources to obtain equipment and to hire people for innovative activities (Schoonhoven et al., 1990). Raising money from external sources creates "information asymmetry" problems between firms and external investors because it is difficult to monitor creative activities such as innovation (Holmstrom, 1989). As a result, it is difficult for firms to raise money for innovation from external investors, unless those investors have developed a specialization in financing innovation.

Venture capitalists are one important category of investors who specialize in financing innovation (Amit, Brander, & Zott, 1998). The structure of venture capital arrangements allows these organizations to overcome many of the information asymmetry problems that plague external financing of innovation. Thus, we propose that access to venture capital, which varies across environments and over time, makes new firms more innovative.

Venture capitalists can support new firm innovation in several ways. They help new firms obtain additional financing, help recruit a management team, identify customers and suppliers, monitor and develop investments by sitting on boards of directors, and engage in strategic and operational planning (Gorman & Sahlman, 1989; Sapienza & Gupta, 1994). In view of these skills of venture capitalists, we propose that new firms are better able to commercialize inventions in industries in which venture capital is plentiful. In contrast, when venture capital is less plentiful, the best source of capital to finance innovation is cash flow from existing operations. Although this source of capital only partially finances innovation in established firms, it does not finance the innovation process at all in new firms (which have no cash flow from existing operations). This argument leads to the second hypothesis:

*Hypothesis 2. New firms have a higher rate of innovation in markets in which financial resources are more plentiful.*

### Manufacturing Intensity

New firms lack the skills and routines that more established firms have to assemble, organize, and monitor the manufacturing resources that are needed for innovation. If innovation in a given market is manufacturing intensive—that is, if it depends on the joint exploitation of manufacturing assets and new technology (Galbraith, 1982)—new firms will have lower rates of innovation than they will have in less manufacturing intensive markets. In manufacturing-intensive markets, knowledge of the manufacturing processes is necessary to correctly specify new product characteristics, and the procedures and equipment for "scale-up" and process development similarly arise through continuous interaction between manufacturing engineers and research and development personnel. New firms often lack access to such knowledge (Gort & Klepper, 1982; Methe, Swaminathan, & Mitchell, 1996).

In contrast, when manufacturing is not important to innovation, new firms innovate at a higher rate. In fact, the routines and planning necessary to take advantage of manufacturing resources often hinder innovation. As Starr and MacMillan observed, "[the] resources available may not be appropriate, but corporate ventures feel obligated to use them" (1990: 89). Unnecessary routines increase bureaucracy, prevent adaptation to changing environments, and slow the innovation process down, promoting innovation in new firms with no established routines. We propose:

*Hypothesis 3. New firms will have a lower rate of innovation in manufacturing-intensive markets.*

### Market Size

New firm innovation is also influenced by the size of the market. New firms often exploit markets that are too small or too hard for established firms to tap (Bhide, 1992; Christensen & Bower, 1996). Because new firms are not constrained by their existing organizational structures, by commitments to serve existing customers, or by supplier relationships, they effectively exploit small, niche markets (Dean, Brown, & Bamford, 1998; Swaminathan, 1995). As a result, the smallness of a market is less likely to be a constraint for new firms, because they, unlike established firms, do not face an opportunity cost of changing markets when they innovate.

Conversely, when a market is large, its size justifies the investment of established organizations in changing their routines (Shane, 2001b). Larger markets also demand more comprehensive capabilities in coordinating marketing and customer care than new firms generally possess (Tripsas, 1997). These arguments suggest the fourth hypothesis:

*Hypothesis 4. New firms will have a higher rate of innovation in smaller markets.*

## METHODS

### Sample

To test the hypotheses, we tracked all 1,397 inventions patented by the Massachusetts Institute of Technology (MIT) between 1980 and 1996, and identified those of the inventions that were licensed to firms during the 17-year observation period. One example of the inventions is a "cross flow filtration molding method" that is "particularly useful for forming complicated shapes from dispersions of particles in a liquid medium." Another example is "a method for forming metal, ceramic or polymer compositions" in which "fine grain metal, ceramic or metal-ceramic or metal-polymer compositions are formed by impinging at least two liquid streams of metal, ceramic and/or polymer, upon each other to form a turbulent mixture having small eddies." There were 964 attempts by firms to innovate using the 1,397 inventions patented by the university. We defined an innovation attempt as an effort by a firm to commercialize a licensed invention. Because more than one firm can license a particular invention, there are more attempts (964) than there are licensed inventions (556). In fact, the range is wide: one invention was licensed by 12 firms, whereas 349 inventions were licensed by only 1 firm.

We followed each of the 964 innovation attempts yearly until they reached the sale of a product, or the license was terminated, or the observation period ended. During our observation period, 197 of the attempts reached a sale. In 338 attempts, the licensee terminated the license. The remaining 429 attempts stayed in the sample until the end of the observation period but did not reach either event.

In total, the analysis included 3,574 firm-license years.

The innovation attempts were undertaken by 340 firms operating in industries with 27 different three-digit Standard Industrial Classification (SIC) codes. The most frequent industries in the sample are SIC 283 (drugs), with 22 percent of the sample; SIC 382 (scientific instruments), with 16.6 percent of the sample; SIC 366 (communications equipment), with 10.8 percent of the sample; SIC 286 (industrial organic chemicals), with 9.7 percent of the sample; SIC 361 (electric transmission equipment) and SIC 355 (special industrial machinery), each with 5.7 percent of the sample; and SIC 357 (computer and office equipment), with 5.3 percent of the sample.

The invention data were collected from the records of the Technology Licensing Office at the Massachusetts Institute of Technology. This office is the administrative unit responsible for management of intellectual property assigned to the university. The records included information about all licensing agreements between MIT and private sector entities.

Our unique data enabled a more accurate test of new firm innovation than has been possible before. As several researchers (e.g., Barnett & Burgelman, 1996) have pointed out, a common empirical challenge for studies of innovation is overcoming sample selection bias, which can distort empirical results. For example, to examine firm newness and innovation, researchers need to observe a set of inventions prior to efforts by new firms to commercialize them. Simple observation of innovations by new firms fails to accomplish this goal because such an effort confounds the invention with its commercialization, and so makes it difficult to distinguish the performance at each stage of activity. Moreover, innovations often emerge simultaneously with the new firms that create them, a situation that makes it difficult to examine the innovation process without sampling on the dependent variable. Finally, new firms potentially draw their inventions from a distinctive pool of new technologies. Because new firms are often spin-offs from established firms (Klepper, 2001), the technologies that they seek to innovate are often a selected sample of inventions that were born in established firms, but passed over by those organizations. This selection bias makes it very difficult to draw generalizable inferences about the performance of new firms at innovation.

Our sample of inventions is uniquely appropriate for this study because it addresses the above challenges. First, MIT patents provide a documented population of new technologies that can be identified after invention, but before commercialization. Second, these inventions provide a documented population of new technologies at risk of commercialization by both new and established firms. Unpatented technologies do not provide these features because researchers cannot identify them after invention but before commercialization. Patents produced by firms do not provide these features because firm patents, by definition, require firm existence.

The sample is also unique in that the commercialization efforts of these inventions are tracked in detail. First, all of the inventions in our sample were at risk of licensing because the MIT Technology Licensing Office marketed them broadly and encouraged firms to license them. Second, because MIT generates significant revenues from technology licensing, it carefully documents the process, including dates during which particular patents are covered by licensing agreements, the legal statuses of licensees, and the stage of commercialization of products that use MIT inventions. As a result, we were able to create, with a high level of accuracy, annual spells for each invention extending from the date of first license until termination of the license, or censoring.

### Measures

***Dependent variable: Innovation.*** We operationalized the dependent variable, innovation, by measuring two outcomes: the likelihood that a licensee would sell a product developed from a licensed invention *(first sale),* and the likelihood that a licensee would abandon a license to that invention prior to any sale *(license abandonment).* While first sale gave external confirmation of invention commercialization, license abandonment gave internal confirmation of abandonment of that effort.

To capture the first outcome, we constructed annual spells that started when a particular firm licensed an invention and ended when a product using the invention was first sold to a third party. The first sale variable was coded 1 in the year the first dollar of sales was achieved; otherwise it was coded 0. We determined first sale by examining records from the Technology Licensing Office, which indicate whether sales have occurred for products or services that employ university-patented technologies. We expected the information on first sale to be highly accurate for two reasons: Licensees were contractually obligated to inform the university of the sale of products or services that used its technology; also, the university had a strong incentive to verify this information as its royalty revenues depend on the sales of licensed technologies.

The second possibility, termination of a technology license during the observation period, could arise for two reasons as well: Because licensees pay ongoing fees, typically annually, to maintain licenses, they often terminate them if the patented inventions do not help them develop commercial products or services. A license may also terminate when the patent on a licensed technology expires (during our observation period, patents expired 17 years after issue). To measure license abandonment, we constructed annual spells in which we used contract records to determine if a license to a patent remained in force. If a patent license was terminated in a given year, license abandonment was coded 1 in that year; otherwise it was coded 0. As above, we expected high accuracy. Because one of the major functions of the MIT Technology Licensing Office is to manage the university's licenses, it maintains excellent records on licensing agreements.

A third possibility was that neither event of interest—first sale or license abandonment—occurred during our observation period. In that case, both were coded as 0 during the observation period and as right-censored at the end of the observation period.

***Firm newness.*** We measured whether a firm was new by whether it existed prior to a focal licensing. If the licensee of a patent was not in existence prior to the license year, a dummy variable was coded 1 to indicate that the licensee was a *new firm*. We gathered these data from the Technology Licensing Office records.

***Environment.*** Industry provided a convenient boundary for our measures of the time-varying characteristics of the licensees' environments—*competition*, *financial resources*, *manufacturing intensity,* and *market size*—since firms in the same industry often compete for the same set of resources. Following prior studies, we defined an industry as the group of firms that supplies a given market using similar inputs (Acs & Audretsch, 1988; Dean et al., 1998).

The U.S. Patent and Trademark Office concordance index specifies which patent class corresponds to a particular industry SIC code. We used this concordance index to determine the characteristics of the industry in which a commercialization attempt took place. Based originally on a concordance developed by Schmookler (1966), this index assigns patents to the three-digit SIC code in which at least two-thirds of the patents in that patent class are used. The U.S. government has assessed the concordance positively (U.S. Patent and Trademark Office, 1985). More recently, management scholars have used this concordance to match university patents to industry (e.g., Shane, 2001a, 2001b). By using this concordance, we were able to gather data on the industry characteristics that we measured.

Our choice was to measure industry at the three-digit SIC code level. While we would have been able to increase the specificity of classification at the four-digit level, the increased precision would have been offset by the reduced precision of the assignment of patent classes to industries, yielding no net benefit. Moreover, our test was conservative. Because the three-digit SIC codes are composed of the average of four-digit codes, measurement at the three-digit level reduces parameter estimates and increases standard errors. Thus, measuring effects at the three-digit level likely understated our results. The following time-varying measures of the environment were constructed:

We measured *competition* in a market as the annual number of firms (both public and private) operating in the industry in which a patented invention was commercialized. Previous researchers have demonstrated that the number of firms in an industry affects the intensity of competition and availability of resources (Hannan & Freeman, 1984; Tushman & Anderson, 1986). We used the Census of Manufacturers as our data source because it is reliable and has been used in several prior studies (e.g., Dean & Snell, 1996).

We measured the availability of *financial resources* as the yearly amount of venture capital funding in an industry, creating a time-varying covariate because venture capital funding shifts significantly across industries over time (Shane & Stuart, 2002). Data from the Securities Data Corporation's venture capital database were used to calculate the annual dollar value of venture capital funding in each industry. Securities Data Corporation is the leading provider of industry-level venture capital data, and the accuracy and validity of its data have been shown in several studies (Lerner, 1994).

We measured *manufacturing intensity* as the ratio of the dollar value of manufacturing and the dollar value of shipments in each industry annually. Following previous researchers (e.g., Dean & Snell, 1996), we used data from the Census of Manufacturers. A time-varying covariate was created as it offered relatively precise measurement.

We measured *market size* as the annual dollar value of shipments in an industry, drawing data from the Census of Manufacturers. This measure was also time varying, because the sizes of markets change as industries evolve (Christensen & Bower, 1996; Utterback, 1994).

### Control Variables

We used dummy variables for three *time periods* (1984–86, 1987–89, 1990–96, with 1980–83 being the omitted period) in the analysis. We chose these periods because specific changes in federal law and MIT policy occurred at those times, changes that may affect commercialization. For example, in 1984 the federal government allowed universities to sell property rights to federally funded inventions, increasing university incentives to achieve revenues through licensing. In 1987, MIT allowed inventor-founded start-ups to provide equity to the university in return for the university's payment of patent costs, reducing capital constraints on inventor start-ups, and potentially reducing pressures to sell products quickly. MIT also reorganized its technology-licensing office, replacing the lawyers who had previously managed the licensing operation with technology field experts. This change allowed for a more vigorous, hands-on approach to licensing. In 1990, MIT permitted inventors to retain their share of royalties even if they held equity in a new company founded to exploit the invention, further reducing capital constraints on new firm technology commercialization.

We also controlled for whether the inventor of a patented technology was also a founder of the new firm attempting to commercialize it. Although many, if not all, university inventors are likely to be involved in the commercialization process in both new and established firms, some researchers believe that inventor-founded firms represent a special case. It is possible that an inventor-entrepreneur will have expertise and tacit knowledge of a technology that can accelerate commercialization (von Hippel, 1994)—or, on the other hand, commitment that prevents abandonment of a failing attempt (Brockner, 1992). We gathered the data on *inventor-founders* from the Technology Licensing Office records.

The number of firms that have licensed a given invention might also affect the commercialization process. On the one hand, if a focal licensee can learn from others' prior commercialization experiences (Argote, Beckman, & Epple, 1990; Greve, 2005; Miner & Haunschild, 1995), a high *number of licensees* might promote first sale. On the other hand, a high number of licensees could bring competition, leading to licensees abandoning a license. We gathered these data from the Technology Licensing Office records and updated the variable annually to indicate how many firms had tried to commercialize a given invention in the prior year.

New firms may also be inclined to license only certain types of inventions. For example, new firms could purposefully choose to license inventions in which established firms are not interested. Such self-selection would have prevented us from examining commercialization attempts for new firms that were drawn from a wide distribution of inventions. For this reason, we included a self-selection control in the analysis (Greene, 2000; Katila & Mang, 2003), constructing a variable, *self-selection,* by estimating the likelihood that a new firm would license a given invention. To construct this correction, we had to assemble a separate data set on all 1,397 patents issued to MIT between 1980 and 1996, and their licensees (if any). To generate the selection correction, we used Lee's (1983) generalization of the Heckman selection model. Predicted probabilities for new firm licensing, with invention and environmental variables as predictors, generated a sample correction variable lambda, where $F_i(t)$ is the cumulative hazard function for invention $i$ at time $t$, $\phi$ is the standard normal density function, and $\Phi^{-1}$ is the inverse of the standard normal distribution function:

$$\lambda_{it} = \frac{\phi\{\Phi^{-1}[F_i(t)]\}}{1 - F_i(t)}.$$

The self-selection correction $\lambda_{it}$ was then included as a control in both the first sale and license abandonment models.

We also controlled for the characteristics of licensed inventions. We used a series of dummy variables to control for the *technical field* of an invention—chemical, drug, electrical, or mechanical (with "other" as the omitted case)—because the commercialization process can differ across types of technology. The existence of technological opportunities, the resource requirements and time needed to exploit them, and the tendency of inventors to disclose their inventions all vary with technology (Cohen & Levin, 1989; Romanelli, 1989).

Since it is also possible that technically radical inventions take longer to develop and sell, we controlled for *technical radicalness*. As did Rosenkopf and Nerkar (2001), we measured technical radicalness as the number of technological subclasses to which an invention was assigned, but from which the invention did not cite prior art patents.

### Analytic Methods

Our analysis employed event history techniques. We used a Cox proportional hazards model to predict the hazard of innovation, developed from our sample of 964 attempts to commercialize inventions (Cox, 1972). The hazard rate of innovation at time $t$, $h(t)$, can be written as follows: $h(t) =$

$h_0(t)\exp[\beta \boldsymbol{X(t)}]$, where $h_0(t)$ is a baseline hazard function (shared across the population) and $\boldsymbol{X(t)}$ is a vector of covariates (varying across individual observations). We followed each innovation attempt by updating the covariates yearly. As is customary in event history analysis, we did this by reconfiguring the data into yearly spells. Each spell was a firm-license-year observation, and the first spell for each attempt was the first year of licensing.

Since innovation has two outcomes of interest—achievement of a first sale and abandonment of a license—we used competing-risks Cox models (Allison, 1984). First sale and license abandonment are mutually exclusive. If a licensed invention is commercialized, the licensee cannot abandon the license prior to first sale; and if a license to an invention is abandoned, the licensee cannot sell the product. In a situation in which a dependent variable has two or more outcomes and the occurrence of either removes the subject from the risk of the other, a competing-risks framework is appropriate (Allison, 1984). To employ a competing risks framework, we looked at one type of outcome at a time, while treating the other type as censored. Thus, first sale is treated as a right-censored case in our models analyzing license abandonment, and license abandonment is treated as a right-censored case in models analyzing first sale (see also Cannella & Shen, 2001).

To control for any invention-specific effects, we used a robust estimation procedure (Lin & Wei, 1989). This estimator allowed us to obtain consistent standard errors derived from the Huber/White robust estimator of variance, and it thus relaxed the assumption that observations within the same cluster (in our case, the same invention observed across multiple years) were uncorrelated (White, 1980). Table 1 shows descriptive statistics and correlations for all variables.

## RESULTS

Table 2 reports the results of the Cox regression analysis conducted to predict how environmental conditions affect new firms' achievement of first sales, and abandonment of licenses. Each model in Table 2 has two equations, one for each outcome in the competing-risks framework. First sale is the dependent variable in models 1a, 2a, and 3a, and license abandonment is the dependent variable in models 1b, 2b, and 3b. Since the two outcomes were modeled as competing risks, the chi-square values reported at the bottom of the table are for

**TABLE 1**
**Descriptive Statistics and Correlations[a]**

| Variables | Mean | s.d. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. New firm | 0.32 | 0.47 | | | | | | | | | | | | | | | | | |
| 2. Competition[b] | 14.49 | 12.56 | .13 | | | | | | | | | | | | | | | | |
| 3. Financial resources[c] | 0.26 | 0.30 | .02 | −.01 | | | | | | | | | | | | | | | |
| 4. Manufacturing intensity | 0.53 | 0.11 | .00 | −.07 | .02 | | | | | | | | | | | | | | |
| 5. Market size[c] | 0.21 | 0.07 | −.04 | .11 | −.30 | −.13 | | | | | | | | | | | | | |
| 6. 1984–86 | 0.07 | 0.26 | −.03 | −.04 | −.08 | −.07 | −.23 | | | | | | | | | | | | |
| 7. 1987–89 | 0.18 | 0.38 | −.01 | −.09 | .02 | −.19 | −.07 | −.13 | | | | | | | | | | | |
| 8. 1990–96 | 0.72 | 0.45 | .03 | .12 | .06 | .22 | .25 | −.46 | −.75 | | | | | | | | | | |
| 9. Inventor-founder | 0.18 | 0.38 | .68 | .14 | −.01 | −.04 | .02 | .00 | .01 | .00 | | | | | | | | | |
| 10. Number of licensees | 2.05 | 1.78 | −.11 | −.05 | .00 | .15 | .06 | −.10 | −.10 | .17 | −.12 | | | | | | | | |
| 11. Self-selection | 1.17 | 0.66 | −.01 | −.06 | −.02 | .09 | .37 | −.08 | .07 | .01 | −.05 | .08 | | | | | | | |
| 12. Chemical | 0.30 | 0.46 | .01 | −.02 | −.04 | −.04 | .03 | −.01 | .03 | −.01 | .04 | −.18 | .06 | | | | | | |
| 13. Drug | 0.29 | 0.45 | −.06 | −.30 | −.09 | −.07 | .33 | .10 | .13 | −.18 | −.13 | .55 | −.41 | .01 | | | | | |
| 14. Electrical | 0.25 | 0.43 | .00 | .33 | .08 | −.07 | −.13 | −.06 | −.13 | .15 | .04 | −.41 | −.38 | −.37 | .02 | | | | |
| 15. Mechanical | 0.03 | 0.18 | −.02 | .09 | −.07 | −.02 | .00 | .01 | −.01 | −.01 | .04 | −.21 | −.12 | −.12 | −.11 | −.08 | | | |
| 16. Technical radicalness | 4.50 | 4.62 | .10 | .12 | .21 | .16 | −.23 | −.12 | −.11 | .20 | .08 | .03 | .12 | −.36 | .04 | −.02 | −.04 | | |
| 17. First sale | 0.06 | 0.23 | .01 | −.01 | .04 | −.01 | .03 | −.03 | .05 | −.02 | .01 | −.02 | .06 | −.01 | −.02 | −.02 | .07 | −.01 | |
| 18. License abandonment | 0.09 | 0.29 | .02 | .03 | −.04 | −.01 | .01 | −.07 | −.01 | .06 | −.02 | .00 | −.01 | −.04 | .04 | .01 | −.02 | .02 | −.07 |

[a] $n = 3{,}574$.
[b] Divided by 1,000.
[c] In millions of dollars.

**TABLE 2**
**Results of Competing-Risks Cox Regression Analysis[a]**

| Variable | First Sale: Model 1a | License Abandonment: Model 1b | First Sale: Model 2a | License Abandonment: Model 2b | First Sale: Model 3a | License Abandonment: Model 3b |
|---|---|---|---|---|---|---|
| New firm | | | 0.01 | 0.37** | 2.66* | −4.61** |
| | | | (0.21) | (0.13) | (1.49) | (1.73) |
| Competition[b] | | | −0.0003 | 0.003 | −0.03* | 0.01† |
| | | | (0.001) | (0.004) | (0.02) | (0.01) |
| Financial resources[c] | | | 0.66*** | −0.58** | 0.23 | −0.85** |
| | | | (0.20) | (0.22) | (0.31) | (0.29) |
| Manufacturing intensity | | | 0.33 | −0.61 | 3.07* | −1.40** |
| | | | (0.73) | (0.48) | (1.72) | (0.49) |
| Market size | | | 4.22** | −1.20 | 6.13*** | −4.36*** |
| | | | (1.50) | (1.17) | (1.87) | (1.30) |
| New firm × competition | | | | | 0.06** | −0.01† |
| | | | | | (0.02) | (0.01) |
| New firm × financial resources | | | | | 0.50 | 0.92* |
| | | | | | (0.41) | (0.47) |
| New firm × manufacturing intensity | | | | | −4.56** | 5.48* |
| | | | | | (1.92) | (2.47) |
| New firm × market size | | | | | −5.85* | 9.15*** |
| | | | | | (2.71) | (2.11) |
| Time period | | | | | | |
| 1984–86 | −0.44 | 0.03 | −0.48 | 0.09 | −0.51 | 0.08 |
| | (0.61) | (0.82) | (0.62) | (0.82) | (0.61) | (0.82) |
| 1987–89 | 0.57 | 1.46* | 0.29 | 1.59* | 0.19 | 1.69* |
| | (0.52) | (0.72) | (0.53) | (0.73) | (0.54) | (0.72) |
| 1990–96 | 0.10 | 1.54* | −0.33 | 1.69* | −0.33 | 1.78* |
| | (0.52) | (0.71) | (0.55) | (0.72) | (0.56) | (0.71) |
| Licensee | | | | | | |
| Inventor-founder | 0.22 | −0.29* | 0.19 | −0.62*** | 0.18 | −0.57*** |
| | (0.18) | (0.14) | (0.25) | (0.17) | (0.27) | (0.18) |
| Number of licensees | 0.13*** | −0.06* | 0.14*** | −0.05 | 0.13*** | −0.05† |
| | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) |
| Self-selection | −0.24† | 0.15 | −0.38* | 0.18† | −0.42** | 0.22* |
| | (0.13) | (0.10) | (0.15) | (0.11) | (0.15) | (0.10) |
| Invention | | | | | | |
| Chemical | 0.47† | −0.08 | 0.25 | −0.07 | 0.08 | 0.07 |
| | (0.26) | (0.17) | (0.28) | (0.20) | (0.29) | (0.21) |
| Drug | 0.32 | −0.32† | 0.05 | −0.30 | 0.04 | −0.26 |
| | (0.30) | (0.19) | (0.31) | (0.21) | (0.32) | (0.23) |
| Electrical | 0.01 | 0.19 | −0.17 | 0.19 | −0.22 | 0.29 |
| | (0.29) | (0.18) | (0.34) | (0.21) | (0.35) | (0.20) |
| Mechanical | −0.57 | 0.21 | −0.79 | 0.24 | −0.85 | 0.31 |
| | (0.64) | (0.34) | (0.67) | (0.36) | (0.67) | (0.35) |
| Technical radicalness | −0.01 | −0.01 | −0.005 | −0.004 | −0.002 | −0.01 |
| | (0.02) | (0.01) | (0.02) | (0.01) | (0.02) | (0.01) |
| Model $\chi^2$ | 77.8*** | | 113.2*** | | 200.8*** | |

[a] The table gives parameter estimates; robust standard errors are in parentheses. $n = 3{,}574$ yearly observations.
[b] Divided by 1,000.
[c] In millions of dollars.
† $p < .10$
* $p < .05$
** $p < .01$
*** $p < .001$
Two-tailed tests for controls, one-tailed tests for hypothesized variables.

both outcomes simultaneously. Model 1 reports the baseline with controls. In model 2, "main effects" are added. Model 3 introduces the effects of the four interactions of new firm, with competition, financial resources, manufacturing intensity, and market size. Here we discuss the results based on the full models (models 3a and 3b in Table 2).

Hypothesis 1 proposes that new firms innovate at a higher rate in high-competition than in low-competition industries. The interaction of new firm and competition is positive and significant in model 3a in Table 2 (with significant main effects), and negative and moderately significant in model 3b, providing cautious support for this hypothesis. New firms are more likely to reach first sale and less likely to abandon a licensed invention if there are a larger number of firms in their industry. In Hypothesis 2, we propose that the availability of venture capital helps new firms at innovation. Hypothesis 2 is not supported. The interaction between new firm and financial resources is not significant in model 3a, and it has a positive sign in model 3b, indicating that the availability of venture capital encourages rather than discourages license abandonment. We return to these findings in the discussion section.

In Hypothesis 3, we propose that new firms have a higher rate of innovation in less manufacturing intensive industries. In model 3a, the interaction between the new firm and manufacturing intensity variables is negative, and in model 3b it is positive and significant, thus confirming this hypothesis. Finally, Hypothesis 4 predicts that newness operates differently in small than in large markets. The estimated negative interaction between new firm and market size in model 3a, and the positive interaction between new firm and market size in 3b, provide support for the argument that new firms innovate more in small markets.

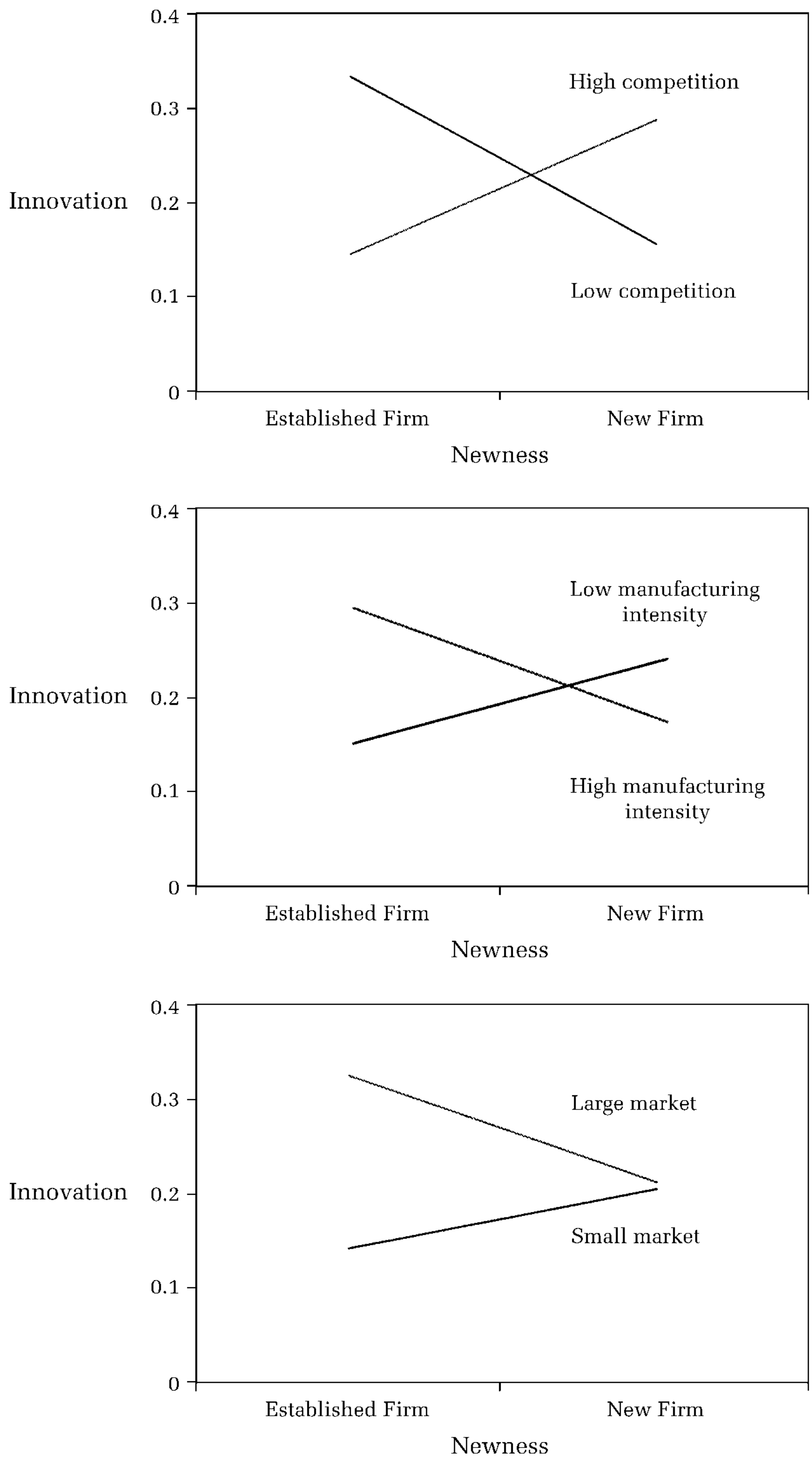
To further illustrate the interaction effects, we have graphed the interactions in Figure 1. The vertical axis in Figure 1 represents the hazard rate of reaching first sale. We used one standard deviation below and above the mean as the range for the moderator variables (i.e., competition, manufacturing intensity, and market size). Other variables were constrained to their mean values (Aiken & West, 1991). Since the baseline hazard varied over time, we used a fixed point in time ($t$ = 2.00; $h_0(2)$ = 0.03) for the graphs (Trevor, 2001). The corresponding graphs for license abandonment result in a substantively similar interpretation (these graphs are available from the authors).

Among the main effects and control variables for which results are presented in Table 2, several interesting patterns were observed. In line with prior work, the effects of being a new firm on innovation are mixed in the absence of interaction effects (models 2a and 2b). New firms seem to be more likely to abandon licensed inventions, whereas the effect on the achievement of first sale is not significant. Comparison of these results with models 3a and 3b shows how adding the interactions changes the view of how newness affects innovation and, thus, confirms the importance of considering firm resources in relation to firm environment. Second, in models 3a and 3b, we also find that inventions that were licensed to companies founded by the inventions' own MIT inventors were disproportionately less likely to be abandoned in all industry environments, potentially indicating inventors' greater commitment to developing their own inventions (Brockner, 1992). Third, in line with the interorganizational learning explanation, inventions licensed by multiple firms were both more likely to be commercialized and less likely to be terminated by both new and established firms in all industry environments. Fourth, interesting patterns emerge from the selection regression that yields the self-selection correction (this regression is also available from the authors). In this selection regression, new firms were more likely than established firms to license inventions that were technically radical, had larger market potential, and were in more competitive markets.

We also conducted several robustness checks to confirm our main results. We tested for the possibility that the effect of competition was an artifact of concentration rather than a demonstration of firm density effects. To test this alternative argument, we examined the effect of concentration, measured as the annual market share of the four biggest firms in each industry, using data from the Census of Manufacturers. When we used concentration in place of the competition variable in interaction with new firm, or as an additional control variable, our original results remained qualitatively the same. Thus, the number of firms captures the effect of a different construct than does concentration. We also investigated whether fixed effects for technical fields possibly confounded the venture capital results since venture capital funding tends to be skewed across technologies. Exclusion of these effects did not change the results.

We also modified the new firm variable to ensure that the particular measure we used did not affect the results. In place of our original dichotomous variable, we used a time-dependent firm age variable that recorded the number of years since firm founding. Unfortunately, the firm age data were not available for all sample firms, reducing the sample for this sensitivity test to 2,837 observations. De-

**FIGURE 1**
**Interactive Effects on Innovation[a]**




[a] Innovation is defined as the hazard of first sale.

spite this smaller sample, the pattern of the original results was supported.

Models that we have discussed so far have focused on how the relationship between innovation and being a new firm changes as a function of the level of the environmental variable (see Figure 1). To probe the interaction results further, we also examined whether new firms were more innovative than established firms under certain environmental conditions because they negated advantages of established firms there. To test for this effect, we used a simple slopes test (Aiken & West, 1991). The test showed that new firms were significantly more innovative than established firms in highly competitive and small markets.

Finally, to test the argument that new firms were more productive at commercializing technically radical inventions (Henderson, 1993), we included an interaction between new firm and technical radicalness in the models (in unreported regressions). When this interaction was entered into the first sale equation with only the control variables, there was indication that new firms indeed were more productive in their innovation efforts when the technology was radical. However, this effect lost significance in the full model, although the coefficients still had the expected signs. Again, this result suggests that measuring the effects of technical radicalness in isolation, without the environmental contingencies, would have led to incomplete understanding of the innovativeness of new firms.

## DISCUSSION

In this article, we study a question that has puzzled several prior researchers: when are new firms innovative? While some researchers have argued that the lack of existing resources makes new firms poor innovators, others have reasoned that the very presence of resources constrains innovation, making new firms more innovative than established firms. Our results indicate that neither explanation is complete. Controlling for factors found to be important in prior work—including the greater tendency for new firms to invest in technically radical inventions, as well as their greater effectiveness at commercializing these inventions (Arrow, 1962; Henderson & Clark, 1990)—we showed that the market environment plays an important role in determining when new firms are innovative. Our results show that new firms are more likely to reach first sale and less prone to abandon efforts to innovate in more competitive, smaller, and less manufacturing intensive markets.

### Future Research Directions

One limitation of this study is the focus on inventions from a single research university. Although MIT accounts for 8 percent of all university patents, making it the largest university in terms of patenting (Henderson, Jaffe, & Trajtenberg, 1998), the findings of this study might still be unique to MIT and should be replicated with data from other settings.

Second, we examined patented inventions. Despite the substantial advantages of studying patented inventions (Katila, 2002), their use as a research sample also limits the generalizability of our results. Patenting is more common in some industries than in others. Because the environmental conditions that give new firms advantages as innovators of patented inventions may not be the same as environmental conditions that give them advantages as innovators of unpatented inventions, our results will generalize best to industries where patenting is important.

### Implications for Theory and Research

Despite its limitations, this study offers important implications for theory and research. First, we address the debate between organizational researchers who argue that firm newness hinders innovation and researchers who argue that firm newness facilitates innovation. Rather than attempt to argue for the innovativeness of new firms under all conditions, we demonstrate that innovativeness depends on environmental characteristics. Although theorists (e.g., Winter, 1984) have argued that environmental characteristics will influence new firm innovation, to our knowledge, this study is the first to explain in detail why this is so. We differentiate between the resources of new and established firms to explain the process and also provide carefully assembled empirical evidence for such a contingency perspective.

The results also advance understanding of the resource-based perspective and the value of firm resources. We revisit the question of whether firms or industries matter (e.g., McGahan & Porter, 1997), showing that the answer is contingent upon the quality of their combination. The value of a resource cannot be determined in a vacuum, but depends on the context in which it is used. We also extend the contingent resource-based view to the world of new firms that have not yet developed resources. Our study asks when—that is, under what environmental conditions—lack of resources is useful, and when it is constraining. Our finding that resource constraints can be enabling is intriguing. Although organizational studies have focused on the negative aspects of scarcity of skills, time, and resources, and strategies to overcome these constraints (e.g., Agarwal, Sarkar, & Echambadi, 2002; Rao & Drazin, 2002), the enabling features of scarcity remain mostly unexplored. This study is among the first empirical steps in this emerging area. We also make a related contribution to the resource-based perspective. Our results speak to an important but untested assumption in the dynamic capabilities view: the assumption that it is important for firms to reconfigure resources as environments change (Teece et al., 1997). In this study, we tested how different types of environments changed the value of organizational resources. In so doing, we provided evidence that the value of resources depends on their environment and that resource value can change rapidly as an environment evolves.

From the perspective of technology strategy, the results have several implications. First, we have identified conditions that help new firms develop products that can be used to compete against established firms. This contribution is valuable because established firms have relatively few tools with which to predict the threat of competition from firms not yet in existence. Second, the results help firms predict the best structural arrangements for innovation, to define when it will be effective to innovate in-house, and when it will be effective to license inventions to new firms for commercialization. Third, the results have implications for understanding the recent discussion on exploration and exploitation in the context of innovation. By definition, all innovative activities that new firms undertake involve exploration, rather than exploitation of their existing routines (cf. March, 1991). Therefore, the study identifies conditions under which exploratory strategies are more likely to be successful.

Our results also contribute to the entrepreneurship literature. Many of the studies in this literature are context-free and contain the argument that new firms that undertake specific strategies, or that possess specific skills, will be more successful. Our results show that such arguments face limits. The performance of new firms depends on their environment. Even if entrepreneurs cannot recognize the constraints and opportunities that environmental conditions impose upon their new firms, these conditions influence their performance. Our results suggest that the environment in which new firms operate needs to be fully incorporated in theories of entrepreneurship.

Our empirical methodology strengthens our confidence in the findings. We explored the advantages of being a new firm by identifying all efforts to commercialize MIT inventions between 1980 and 1996. As a result, we avoid the problem of sampling on the dependent variable. Moreover, by examining university patents, we compared inventions that are simultaneously at risk of commercialization by new and established firms, thereby mitigating the problem of selection bias. We also created a selection correction to account for the fact that some inventions can be more likely than others to lead to the founding of new firms. Finally, our outcome measures were appropriate to the phenomenon we studied. According to Schoonhoven et al., (1990), first sale is a significant entrepreneurial event for a new company. Moreover, the use of this variable is consistent with Rosenkopf and Nerkar's (2001) and Sørensen and Stuart's (2000) calls for studies that examine the commercialization of new technologies.

Despite these efforts, we did not find support for all of our hypotheses. The results that show that new firms are not more innovative in markets with more venture capital are in line with other recent empirical work (e.g., Zucker, Darby, & Brewer, 1998) but contradict theoretical expectations and thus beg further discussion. One explanation could be that venture capitalists are not good at identifying industries that will generate revenues quickly. As a result, sometimes they invest in hot industries like biotechnology, where reaching the first sale turns out to be slow and difficult. Another explanation could be that venture capital funding and product sales are alternative ways to access capital. If venture capital is widely available, new firms do not need to sell products to finance the development of technology. A third explanation is that formal venture capital is less important as a source of capital for the commercialization of new technologies than is popularly believed. Venture capital may lag behind rather than lead innovation. Angel investing, contract research, and government programs, such as Small Business Innovation Research grants, may be more important sources of capital for firms at early stages of technological development. Future research should further investigate this question.

## Conclusion

This study extended the contingent resource-based view to the world of new firms that have not developed resources yet aspire to innovate. The conventional wisdom is that low-competition, resource-rich, and high-demand environments support innovation. We found that these environments only supported innovation in firms that already possess resources, whereas new firm innovation was greater in markets that were crowded, resource-poor, and small. Although these results provided interesting answers to our research question as to when new firms are innovative, they also raised more questions than we could answer here. Do the same environments that make new firms innovative also make them financially successful, or long-lived? And how can established firms emulate new firms to overcome the liabilities of competence? These and other questions provide intriguing puzzles for future work.

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