Entry by Spinoffs

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Entry by spinoffs from incumbent firms is investigated for the laser industry. A model in which spinoffs exploit knowledge from their parents is constructed to explain the market conditions conducive to spinoffs, the types of firms that spawn spinoffs, and the relationship of spinoffs to their parents. The model is tested using detailed data on all laser entrants from the start of the industry through 1994. Our findings support the basic premise of the model that spinoffs inherit knowledge from their parents that shapes their nature at birth. Implications of our findings for organizational behavior, business strategy, entry and industry evolution, and technological change are discussed.

Key words: spinoff; entry; firm capabilities

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1. Introduction
Models and metaphors from biological evolution are increasingly being used in the analysis of organizations (Aldrich 1999), business strategy (Barnett and Burgelman 1996), and industrial competition (Nelson 1995). Considerable mileage has been extracted from the fundamental concepts of variation and selection, both of which have clear counterparts in industrial competition. Much less use has been made of a third important aspect of biological theories of evolution, heredity, which involves reproduction and transmission of genes to offspring (Nelson 1995, p. 54). In this paper, we use the notion of heredity to analyze a distinctive class of industry entrants, spinoffs, that have a clear parental heritage. Spinoffs are entrants founded by employees of firms in the same industry. Despite the prominence of spinoffs in industries such as semiconductors (Braun and MacDonald 1978, pp. 121–145; Malone 1985) and disk drives (Chesbrough 1999), we have little knowledge about why they are more prevalent in some industries than others, the market conditions that favor their formation, and the types of firms that spawn them. To address these questions, we develop and test a model in which spinoffs inherit knowledge from their parents, where knowledge may be thought of as the industrial counterpart to genes (cf. Nelson and Winter 1982, pp. 14–16).

We test the model using detailed data we collected on the evolution of one industry, lasers, where spinoffs have been prominent. Using an annual buyers’ guide, we identify every laser producer and the years they produced each type of laser from the start of the industry through 1994. We also trace the heritage of every producer, which enables us to identify the spinoffs and their parents. Our analysis focuses on the kinds of firms that spawned spinoffs, the relationship of spinoffs to their parents, and the market conditions conducive to spinoffs. Our findings provide considerable support for the basic premise of our model that spinoffs inherit general technical and market-related knowledge from their parents that shapes their nature at birth. Nearly all spinoffs initially produce a type of laser their parent had produced. Each type of laser a firm produced appears to have been a separate source of spinoffs, with spinoffs drawing narrowly on the parent firm’s experience in the spinoff’s initial laser. More successful firms, which are presumed to have acquired greater knowledge, have higher spinoff rates. Spinoffs fall off over time in types of lasers in which knowledge became more embodied in physical capital, making it less accessible to employees. We also find support for various other predictions of the model concerning how demand conditions, acquisitions, and geographic concentration of producers affects the likelihood of spinoffs.

Our findings have numerous implications regarding organizational behavior and business strategy, the determinants of entry, and the welfare effects of spinoffs. Firms are often described as having distinctive capabilities, but why they differ is less clear. In the case of spinoffs, their differences can be traced directly to their parents, who provide...
with distinctive, but limited, knowledge. Rather than search for the most profitable markets to enter, as firms are often advised to do, spinoffs need to devise a strategy to capitalize on their limited information. In nearly all theories of industrial competition, entry is linked to incumbent firms earning supranormal profits. Spinoff entry, though, is driven principally by parental and not market developments, which may help explain why empirical studies fail to find much connection between industry entry rates and incumbent firm profitability (Geroski 1995). In our model, spinoffs have incentives to develop product variants their parents would not find profitable. This can be socially beneficial, as Gordon Moore of Fairchild Semiconductor and Intel fame has argued concerning the development of Silicon Valley (Moore and Davis 2004). Klepper (2002b) similarly implicates spinoffs as the key to why Detroit emerged as the capital of the U.S. automobile industry, and our findings corroborate the link between firm spinoff rates and industry agglomeration.

This paper is organized as follows. In §2, we review prior work relating to spinoffs. In §3, we present our model and derive various predictions from it. In §4, we review the evolution of the laser industry and provide an overview of the spinoff process. In §5, we estimate three logit models concerning the firm and market characteristics influencing the incidence and timing of spinoffs. In §6, we discuss the implications of our findings and offer concluding remarks.

2. Prior Work on Spinoffs

Few studies have analyzed spinoffs. Garvin (1983) analyzes spinoffs across a range of industries, Brittain and Freeman (1986) analyze spinoffs in the semiconductor industry, and Franco and Filson (2000) and Agarwal et al. (2004) analyze spinoffs in the disk drive industry. Combined with the broader literature on employee start-ups of all kinds, certain themes emerge about spinoffs that provide a useful backdrop for our model.

Employee start-ups in technical industries are generally founded by well-educated and experienced employees of firms with similar technologies and markets (Cooper 1984, 1986). A common finding is that employees leave to start their own firms after becoming frustrated with their employers (Garvin 1983). Their frustration is often related to having an idea about an innovation or a new (sub)market rejected by their employer. Differences of opinion can also result from leadership changes in a firm. Brittain and Freeman (1986) find that semiconductor firms that hired a CEO from outside the firm or were acquired by nonsemiconductor firms had higher spinoff rates, which they attribute to tensions about the strategic direction of firms associated with control changes.¹

Garvin (1983) presents anecdotal evidence from a number of industries about spinoffs being concentrated in younger industries. Based on the logic of the product life cycle (Utterback and Abernathy 1975, Klepper 1996), Garvin argues that in younger industries knowledge is more likely to be embodied in human rather than physical capital. This facilitates the transfer of knowledge to spinoffs through their founders. He also argues that product designs are less settled in younger industries, leading to a higher rate of introduction of new product variants. This creates new market niches, which are often difficult for incumbent firms and industry outsiders to evaluate, thus providing distinctive opportunities for the employees of incumbent firms to exploit. For example, spinoffs in the disk drive industry developed new, smaller disk drives that their parents chose not to pursue even after developing prototypes of the new drives (Christensen 1993). If spinoffs respond to distinctive types of market developments such as the emergence of niches or submarkets, it may help explain Brittain and Freeman’s (1986) finding that the rate of spinoffs of semiconductor firms was not closely related to the overall rate of entry, exit, or market growth in semiconductors.

Brittain and Freeman (1986), Franco and Filson (2000), and Agarwal et al. (2004) analyze the kinds of firms that had higher spinoff rates. Brittain and Freeman find that semiconductor firms that produced a wider range of semiconductor products, were early entrants into one or more product groups, and that produced primarily semiconductors had higher spinoff rates. They interpret the first two factors as influencing the amount of knowledge employees have to draw on to start their own firms, where early entrants are assumed to be more innovative and thus more knowledgeable. Firms whose primary business was not semiconductors were assumed to rotate their employees across different businesses, limiting their access to the knowledge they needed to start their own firms. In the disk drive industry, earlier entrants into new submarkets and firms with superior technology also had higher spinoff rates (Franco and Filson 2000, Agarwal et al. 2004).

These findings suggest certain themes that help frame our analysis. First, spinoffs exploit knowledge their founders acquire from their employers, who are commonly referred to as their “parents.” Industry and firm conditions bearing on the amount and kind of knowledge firms have and the accessibility

¹ Mitton (1990) recounts how control changes in San Diego biomedical firms led to disagreements about strategic direction that resulted in spinoffs.
of the knowledge to their employers all influence the rate of spinoffs. Second, spinoffs pursue ideas involving new niche markets or technologies their parents are unwilling or slow to pursue. Industry conditions favorable to the creation of niche markets are thus conducive to spinoffs, as are circumstances such as control changes that may cause firms to miss opportunities. Third, spinoffs are a distinctive form of entry that is not responsive to market conditions in the same way as other kinds of entry.

3. Theory
We develop a simple model that can parsimoniously explain the past findings about spinoffs and also guide the empirical analysis of laser spinoffs. Industry competition is modeled, and it is shown how learning can provide opportunities for profitable entry by spinoffs even when competition drives the returns to zero for other types of entrants. Models of employee start-ups generally do not restrict the start-ups to the same industry as the parent and thus abstract from the effects of market competition on spinoff entry (cf. Pakes and Nitzan 1983, Anton and Yao 1995, Bankman and Gilson 1999, Hellman 2002, Cassiman and Ueda 2003).

3.1. Model
We use a Hotelling-like model to allow spinoffs to enter product niches, as reported in the empirical literature. Different variants of an industry’s product are represented by points on the [0, 1] interval. Buyers purchase one unit of the variant that maximizes their utility. Each buyer has a preferred variant corresponding to a point in [0, 1]. If all sellers charge the same price, buyers purchase the variant closest to their preferred point. Buyers’ preferred points are uniformly distributed on [0, 1].

Sellers can offer a variant for sale by choosing a point on [0, 1] and investing in the know-how needed to produce and market their variant. The success of this investment conditions the unit cost of production and hence the gross profit per unit of output. The more successful the effort, the smaller the market share the firm needs to earn sufficient gross profit to cover its know-how investment. Let \( \alpha \) denote the expected market share needed to cover its know-how investment. Entry at any other location yields a market share of \( \alpha \). This is insufficient to earn positive expected profits and thus entry will not occur, but if firms located more than \( 2\alpha \) apart entry would occur and all firms would capture smaller market shares.

The model is extended to allow for variations in the success of firm know-how investments and other factors that subsequently affect entry. Firms whose investments are least successful do not earn sufficient profits to justify staying in the industry and exit. They are replaced by new entrants at the same location. If demand at a location turns out to be permanently greater than expected, the market share needed for profitable entry will fall below \( \alpha \), which will also induce entry by new firms.

Spinoff entry is spurred by successful firm investments in research and development (R&D) and marketing know-how. Such investments are assumed to generate knowledge about how to develop variants of the firm’s product at a lower cost than its initial variant.2 If such knowledge is generated, it is assumed that only a market share of \( \alpha^* < \alpha \) is needed for profitable entry at any point in the firm’s market area, where \( \alpha^* \) is assumed to be greater than \( 0.5\alpha \) to keep the model tractable. The knowledge is assumed to be accessible only to the firm and its employees. Let \( p_f \) denote the probability that the firm recognizes the opportunity and \( p_e \) that an employee recognizes the opportunity. If both recognize the opportunity, the firm can exploit it first, reflecting its head start over a potential entrant. If the firm does not pursue the opportunity, then the employee can enter through a spinoff. The firm can respond to spinoff entry by locating its own product variant in its market area, but it is assumed it will do so only if it is profitable. Furthermore, it is assumed that employees cannot credibly signal whether they will follow through on a threat to develop a spinoff and thus the firm cannot feasibly contract with its employees not to form a spinoff.3

2 Successful firms may also generate valuable knowledge pertaining to locations outside of their market area. As will become apparent, these opportunities will not provide a basis for spinoff entry because firms would have the same incentive as their employees to exploit such opportunities, and it is assumed that firms always have a head start over their employees in pursuing opportunities. Consequently, we abstract from opportunities that may lead firms to diversify within their industries.

3 Bankman and Gilson (1999) make a similar assumption to explain venture-capital backed spinoffs. If firms cannot tell which, if any, of their employees will start a spinoff, then every employee could hold up the firm and the firm could not feasibly contract to prevent entry by spinoffs.
Suppose that a firm located a variant of its product in its market area. The maximum additional market share it could capture, which would occur if it located the variant at the extreme of its market area, is $0.5\alpha$. Therefore, on its own it would not be profitable for a firm to produce a variant of its product. It would be profitable for a spinoff, though, to produce a product variant located at the extreme of its parent’s market area. It would capture a market share of $0.5\alpha$ from its parent and $0.5\alpha$ from its other neighbor, for a total market share of $\alpha > \alpha^*$. Moreover, it would not be profitable for either its parent or other neighbor to retaliate or for a subsequent spinoff to enter in its market area because the maximum additional market share that could be captured would be $0.5\alpha$. But if a firm were sure of a spinoff, then it would be profitable to develop a variant of its product internally and preempt the spinoff. The firm would capture an additional market share of $0.5\alpha$ and would avoid the loss of market share of $0.5\alpha$ to the spinoff, hence its gain would exceed $\alpha^*$.

This brings out two conditions in which spinoff entry will occur. One is when the firm does not recognize the opportunity generated by its know-how investment but an employee does, which occurs with probability $(1 - p_e)p_e$. The other is when the firm recognizes the opportunity but assesses $p_e$ to be low enough to warrant the gamble that a spinoff will not enter. While a spinoff would gain a market share of $\alpha$ from entry, the firm’s net gain from entry of a product variant is only $0.5\alpha$, reflecting that the firm cannibalizes some of its own market by entering a product variant, whereas the spinoff has no market to cannibalize. Consequently, if the chance of a spinoff is sufficiently low, it pays the firm to gamble that a spinoff will not enter (cf. Klepper and Sleeper 2000). Then, with probability $p_e$, a spinoff occurs.4

This simple model can help explain many of the past findings regarding spinoffs. A necessary condition for a spinoff is that a firm uncovers knowledge that its employees learn, which is consistent with the finding that spinoffs exploit knowledge from their parents. In the model, this only occurs in successful firms, which can explain why innovative firms have higher spinoff rates. Each product location that a firm occupies is a separate source of spinoffs, so firms with broader product lines in an industry have more spinoffs, consistent with past findings. Spinoffs pursue ideas their parents decline to pursue, either because they do not recognize their value or because they gamble a spinoff will not develop them. This is consistent with employees often founding spinoffs to develop ideas rejected by their parents. Normally this is associated with bureaucratic inertia or by the firm being captured by its existing customers (Christensen 1993), but the model suggests that it may simply be due to the different incentives of spinoffs and parents to develop variants of their parents’ products.5

Spinoffs capture a market share of $\alpha$, which is smaller than the market share of other types of entrants. This is consistent with spinoffs entering product “niches.” These are not new niches, though, as emphasized in other theories. Rather, spinoffs have smaller market shares than other types of entrants because they do not need as large a market share as other entrants to be profitable because of the learning exploited by their founders. Relatedly, spinoff entry does not depend on favorable market conditions; as long as expected demand is realized, spinoffs will be able to capture a market share of $\alpha$, which is more than needed for spinoffs to be profitable. In contrast, favorable demand conditions are required to induce entry by other firms. This would explain why spinoff entry does not appear to be responsive to market conditions in the same way as entry of other firms. Note that unfavorable demand conditions could compromise spinoff entry. If demand in a market area is less than expected, spinoffs will need a greater market share than $\alpha^*$ for entry to be profitable, and if the needed market share exceeds $\alpha$, then spinoff entry will be rendered unprofitable. Entry by other firms will also be unprofitable under these circumstances. This suggests an asymmetric effect of demand conditions on the entry of spinoffs versus other firms. Unfavorable demand will depress entry of both spinoffs and other firms, whereas favorable demand conditions will induce entry by other firms but are not necessary for the entry of spinoffs.

Spinoff rates appear to be higher when firms are acquired. Acquisitions bring new leadership, and if this lowers the probability $p_e$ of firms recognizing

4 It has been implicitly assumed that the equilibrium with the initial entrants located $2\alpha$ apart is sensible even if the initial entrants anticipate future niche opportunities within their market area and recognize the possibility of spinoffs. As long as the possibility of spinoffs is sufficiently small, this will in fact be the case. Locations further apart than $2\alpha$, say at $2\alpha + \varepsilon$, where $\varepsilon$ is infinitesimally small, would still induce entry. An entrant at the midpoint between its neighbors could capture a market share greater than $\alpha$ without fear of further spinoffs because spinoffs could capture a maximum market share of $0.5\alpha + \varepsilon/4$ and thus would not be profitable. Firms could locate $2\alpha^*$ apart to forestall the possibility of spinoffs, but as long as the probability of a spinoff were sufficiently small, this would not be profitable.

5 This implication of the model also contrasts with predictions of agency theories. These theories envision employees withholding ideas from their parents due to contracting problems even when the ideas could be more efficiently developed by their parents (e.g., Anton and Yao 1995). These and related theories (Hellman 2002, Cassimani and Ueda 2003) also predict spinoffs developing ideas that are peripheral to the interests of their parents, whereas the model predicts spinoffs developing ideas that fall directly within their parents’ market areas.
learning opportunities, then it will raise the probability of spinoffs in the model. Last, and more tangentially, spinoffs will only occur if the knowledge generated by firms about new opportunities is accessible to the firm’s employees. If the character of knowledge changes along the product life cycle and it becomes more embodied in physical than human capital, causing it to be less accessible to employees, then this will decrease the spinoff rate in the model.

3.2. Testable Hypotheses
The implications of the model suggest various relationships to examine for laser spinoffs. Data are available on the different types of lasers produced by each firm, including the initial laser(s) produced by each firm. Different laser types tend to define different markets. Consequently, the model implies that spinoffs should initially produce similar types of lasers to their parents. More generally, it will be explored how the probability of a firm spawning a spinoff initially producing a particular type of laser is related to the firm’s experience producing that laser and other types of lasers. The model suggests that it should only be related to the firm’s experience with the particular laser type.

No firm output data are available, but data are available for each firm on the number of years it produced lasers. Using this as a measure of success, the model implies that longer-lived laser producers should have higher spinoff rates. Data were collected on which laser firms were acquired by other laser firms and also by firms from other industries. It will be explored whether each type of acquired firm had a higher spinoff rate and whether the spinoff rate was higher around the time the firms were acquired, as suggested by the model. Entry rates of firms other than spinoffs—the number of entrants other than spinoffs divided by the number of producers—can be constructed for each type of laser. Using this entry rate as a proxy for demand conditions, the model suggests that deviations below the mean in entry rates of firms other than spinoffs should have a greater effect on firm spinoff rates than deviations above the mean.

Two laser types evolved further along the product life cycle, and the model implies that the spinoff rate of firms producing these lasers should have declined over time relative to spinoff rates of producers of other laser types.

Various measures can be constructed that might serve as proxies for knowledge generated by the firm. One such proxy is age—it might be expected that firms begin with limited knowledge and if successful invest in R&D and marketing to increase their know-how (Braden 1977, pp. 27–29; Roberts 1991, pp. 166–182; Bhide 2000, pp. 29–68, 207–259). If so, the model implies that firm spinoff rates should rise with age. Data are also available for laser entrants that diversified from other industries on their preentry patenting rates. It might be expected that more intensive patentees would have more knowledge for employees to exploit, in which case the model implies that they should have higher spinoff rates. Last, data are available on the geographic location of each firm. Spinoffs are normally formed by teams of founders, with team members sometimes coming from different firms. Such teams might have been easier to assemble in areas with a greater density of laser firms, suggesting that firm spinoff rates should be higher in such areas.

4. Overview of the Laser Industry and the Spinoff Process
The laser is based on the idea of stimulated emission postulated by Einstein in 1916. If an electron in an excited state is bombarded by a photon of proper energy, another photon of identical energy will be emitted. Stimulated emission requires inverting a population of electrons from a low to an excited state, called a population inversion. Charles Townes of Columbia University first achieved a population inversion in 1954 by passing a beam of ammonia molecules through an electric field. The novelty of his approach was the incorporation of an oscillator cavity to reflect the emitted photons, leading to further stimulated emission of photons. The breakthrough to the laser occurred in 1958 when Townes and Arthur Schalow of Bell Labs proposed enclosing the cavity for stimulated emission in a pair of reflecting mirrors that would reflect only photons of energy corresponding to a selected wavelength in the visible light range. This would create a buildup of reflected photons, a small part of which would be allowed to escape through a small hole in one of the mirrors, yielding a tightly collimated beam of light of a single wavelength with all waves in phase. These qualities, along with the great potential intensity of the light, are the distinguishing features of laser light that makes it useful for a wide range of applications.

The first operating laser was developed in 1960 by Theodore Maiman of Hughes Laboratories using a doped synthetic ruby crystal as the laser medium. Subsequently, a wide range of materials have been made to produce laser light of varying wavelengths. Nine different types of lasers can be distinguished that draw on different types of expertise and service different applications. They are solid-state (crystal), semiconductor, chemical dye, and six types of gas.

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6 This section draws primarily on Bromberg (1991), Hecht (1992), Harbison and Nahory (1997), and especially the monthly issues from 1965–1994 of the trade journal Laser Focus.
lasers: helium-neon (HeNe), carbon dioxide (CO2), ion, excimer, helium-cadmium (HeCd), and a catchall category of all other gas lasers.

We used an annual Buyers’ Guide published by Laser Focus to identify all U.S. commercial (non-military) laser producers, their location, and each of the nine types of lasers they produced for the period 1961–1994. The first commercial laser producer entered in 1961. Early commercial lasers were used primarily for research and military sales exceeded commercial sales, with defense contractors like Hughes and Martin Marietta among the earliest entrants into the industry. Over time, many new lasers within existing categories were developed and whole new categories, including the helium cadmium and excimer lasers, were introduced, and numerous major and minor improvements in existing lasers increased the range of applications they serviced. This greatly expanded the commercial laser market and reversed the balance between commercial and military sales, leading some of the defense contractors to enter the commercial market. The number of U.S. commercial laser producers grew steadily to 136 in 1994, with similar developments occurring in Europe and Japan.

There has been considerable turnover of laser producers. Only 25 U.S. firms produced lasers for at least 20 years, and only 2 of the 24 pre-1965 U.S. entrants and 7 of the 94 pre-1970 U.S. entrants were still in the industry in 1994. At one point, the two leading U.S. firms, Spectra Physics and Coherent, accounted for 30% of worldwide sales (Laser Focus 1974, p. 20), but their market share appears to have declined considerably in recent years as inroads have been made by Japanese producers, European firms, and more recent U.S. entrants. Entrants located throughout the United States, but especially in four areas: northern California around Silicon Valley, southern California around Los Angeles, and in metropolitan New York and Boston, which respectively account for 15%, 13%, 7%, and 7% of the entrants.

The high turnover of firms limited the number of different types of lasers produced by U.S. firms. Over their lifetimes, 55% produced 1 laser, 20% 2 lasers, 23% 3–6 lasers, and 2% 7–9 lasers, with the average equal to 2. This was considerably different among the longer-lived firms. The firms that survived at least 20 years produced an average of 4.6 of the 9 laser types over their lifetimes. Most of their diversification occurred in their early years; by age 10, they had already produced 3.2 different types of lasers. Certain lasers tended to be produced in tandem, reflecting technological relationships among the lasers, particularly the six gas lasers. To probe firm diversification patterns, Teece et al. (1994) developed a statistic to measure the extent to which firms disproportionately produced any two products relative to the overall rate at which each product was produced individually. Applying their statistic to each pair among the nine laser types reveals two distinct clusters of lasers involving the six gas lasers. Firms were significantly (at the 0.05 level) more likely to produce the HeNe, ion, and HeCd lasers together, reflecting that the three lasers used similar components and were improved through similar innovations. Firms were also significantly (at the 0.05 level) more likely to produce CO2, excimer, and other gas lasers together, with the CO2 and excimer link reflecting that excimer lasers grew out of the transversely excited action (TEA) CO2 laser, itself an innovation in CO2 lasers. The other main significant cluster of lasers involved semiconductor and solid state lasers, possibly reflecting the later innovative use of semiconductor lasers to excite Nd:Yag solid state lasers.

The trends in the markets for individual lasers are similar to the overall trends. In recent years, however, the number of HeNe, CO2, and dye producers has declined due to challenges from semiconductor and solid state lasers. Most of the nine laser types have multiple varieties that are used for different applications and are produced in modest volumes by different firms. There are two noteworthy exceptions to this pattern: HeNe and ion lasers. HeNe lasers are inexpensive, low-power lasers whose design has stabilized over time. They are produced in large volumes and competition has focused on their price, with a great deal of effort devoted to improving the production process of HeNe lasers. Ion lasers, especially argon ion lasers, have also developed large-volume industrial applications. Similar to HeNe lasers, the design of industrial ion lasers has stabilized and competition has focused on price, which has also contributed to considerable effort being devoted to improving the production process.9

7 We matched consecutive Buyers’ Guides, adjusting for name and address changes and treating acquired firms as continuing producers if acquired by a nonlaser firm and censored exits if acquired by a laser firm. The Buyers’ Guides have been published since 1966. Data for earlier years are based on Bromberg (1991), Semiconductor Products (1963), and Thomas’ Register of American Manufacturers, 1963–1966. Acquisitions were identified based on a search of the monthly issues of Laser Focus.

8 The other significant links involved semiconductor lasers with both HeNe and HeCd lasers and other gas lasers with CO2, excimer, and HeCd lasers.

9 Short-wave semiconductor lasers, which are heavily used in CD players, printers, and more recently bar-code scanners, have also followed a similar evolution to HeNe and ion lasers. This is not especially relevant for our purposes, though, because these lasers have been dominated by Japanese firms, and U.S. producers of semiconductor lasers have specialized in long-wave semiconductor lasers used primarily in communications.
We attempted to trace the lineage of every producer using various business directories, U.S. Patent Office records, Laser Focus Buyers’ Guide listings of laser component and system producers, firm announcements in Laser Focus, publication searches for initial officers, and the Web. We identified 293 “preexisting” firms that produced other products at least four years before lasers. For each we determined its founding year, the number of (nonlaser) patents it was issued in the five years before its entry into lasers, and (when available) the products it produced in the three years before entry into lasers, where the firm’s entry year is based on its first listing in Laser Focus. We identified 79 of the other 193 de novo entrants as spinoffs based on one or more of their founders (or principals if we could not identify their founders) having previously worked for another laser firm.

For each, we determined its main parent firm based on where its founder(s) had been employed and its initial laser based on the first laser it produced. Using Laser Focus and Bromberg (1991), we also determined which of the spinoffs purchased or licensed technology from their parents, were sued by their parents for infringement, or had parents that researched or produced for themselves or the military (but not commercially) the spinoff’s initial laser. We were also able to compile information for approximately 30 of the spinoffs on their initial strategies relative to their parents.

For each of the main laser types, we plotted annual entry, exit, and the number of firms and constructed a timeline for each of the parents of the spinoffs initially producing the laser type. The timeline for each parent reflected the years it produced the particular laser type, the years it produced lasers of any kind, the years of its spinoffs, the nature of the spinoffs (whether the parent sold or licensed inputs to the spinoff, sued its spinoff for infringement, or researched or produced for itself or the military, but not commercially, its spinoff’s initial laser), whether and when the parent was acquired by a nonlaser or laser firm, and various characteristics about the parent, including the region in which it entered. Rather than present the figures, which are contained in Klepper and Sleeper (2000), various tabulations are used to convey some of the most pronounced patterns in the figures. The tabulations are selective and descriptive. In the next section, we use formal methods to test all the hypotheses.

First, consider the relationship between the lasers produced by the parents and their spinoffs. For all 79 spinoffs, we tabulated the number of instances in which the spinoff produced a laser that its parent had previously produced. As predicted, nearly all the spinoffs initially produced lasers that their parents had previously produced. In 66 of the 79 spinoffs, the parent produced the spinoff’s initial laser at or before the entry of the spinoff. In seven of the other 13 spinoffs, the parent did not commercially produce the spinoff’s laser before the spinoff but either produced or researched it for itself or the military. This overlap is impressive in light of the fact that 55% of the firms produced only one laser type (the average number was two) and only nine of the spinoffs were supplied inputs or licensed technology by their parents.

Further insight into the model can be gleaned from the approximately 30 spinoffs for which we have qualitative information about their initial strategies relative to their parents’ strategies. The spinoffs developed or planned to develop very similar lasers to their parents. About a third of the spinoffs produced a custom variant or did contract research in their parent’s laser, another third produced a higher or lower power (and price) version of their parent’s laser, and the remaining third intended to develop or search for a way to develop a novel variant of their parent’s laser. These strategies are suggestive of small initial markets, consistent with the portrayal in the model of spinoffs entering small market niches.

For a smaller number of spinoffs, we have more detailed information based on trade information and interviews with company personnel about how they...


11 Among the other firms, 44 had founders or principals from universities and government labs, 25 had founders or principals employed by nonlaser firms, 24 had founders and principals we could not trace, and 21 we could not trace at all (and were excluded from the statistical analysis).

12 Sixty-four of the firms were identified based on a report in Laser Focus, with the other 15 identified through publication searches. A few of the latter were suspicious based on little overlap between spinoff and parent, but we included them nonetheless. We also included four spinoffs whose founder(s) worked for another firm that researched or produced lasers for the military or itself but did not initiate commercial production of lasers until after the spinoff. We conducted the statistical analysis with and without these firms, which had little impact on our estimates.

13 For the 12 firms with multiple founders from different firms, we based the identification of its parent on the number of founders from each firm and reports in Laser Focus on the influence of the various founders on the firm.

14 For the small number of spinoffs that produced multiple lasers over their entire (generally short) lifetime, we chose as their initial laser the most important one based on reports in Laser Focus and listings in the Buyers’ Guides. For five spinoffs, information from Laser Focus indicated that a laser they produced in their second year was their main laser. Accordingly, this laser was designated as their initial laser.

15 Other studies of technical start-ups have also found that start-ups begin with modest strategies (Braden 1977, pp. 27–29; Roberts 1991, pp. 166–168).
evolved over time. Table 1 presents brief, illustrative profiles of spinoffs in each of the eight noncatchall laser types (this excludes the category of other gas lasers). The model depicts spinoffs as capitalizing on know-how about product variants gained at their parent that the parent could have pursued but did not. In all eight cases, the spinoff did exploit know-how about its parent’s laser or a variant of its parent’s laser gained while working for the parent. In all eight cases the parent could have pursued the technology itself but with one exception either did not aggressively pursue it or abandoned it altogether. No doubt part of the ability of the spinoffs to use technology developed at their parents stemmed from their parents not actively pursuing the technology themselves, thus limiting their ability to protect it as a trade secret. Moreover, three of the spinoffs licensed technology from their parent and one used technology its parent did not fully control. Two spinoffs did encounter legal challenges from their parents, but both ultimately were able to proceed with the technology. We found only one other reported instance of legal action, suggesting that spinoffs generally did not infringe on technology developed by their parents.  

The model depicts spinoffs as servicing markets that overlapped with their parents and also were related to, but differed from, their parents. At some point, all eight of the spinoffs serviced similar markets to their parents. They all seem to have tried to develop related but different markets from their parents as well. The majority were successful and opened up significant new markets for their lasers. No doubt this helped insulate them from competition with their parents, who generally continued to produce the laser their spinoff produced. This was true generally. Among the 51 parents producing their spinoff’s initial laser at the time of the entry of the spinoff, 41 either continued to produce the laser for three more years, sold or licensed its technology to its spinoff, or was censored (i.e., acquired by ever produce a laser (in which case they would not make it into the data set). Interviews with founders of various spinoffs suggested that firms could draw on a diverse set of sources for technology, enabling spinoffs to avoid infringing on their parents. Specifically, Bell Labs and the military were both sources of technology, and patents generally were not difficult to invent around. Furthermore, in a number of instances spinoffs pursued technologies their parents were not interested in, as reflected in Table 1. Noncompete covnants generally do not seem to have been enforced to stop spinoffs, which in part may have reflected the large number of spinoffs in California, where noncompete covenants have limited force.

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16 This may understate the extent of infringement if spinoffs that did infringe were challenged by their parents and were less likely to
The parents of the spinoffs were also distinctly successful, which may also have contributed to their continued production of the lasers initially produced by their spinoffs. The main measure we have available to gauge the success of the parents is how long they survived. Many of the parents were either acquired or were still in the industry in 1994 and so their years of survival were censored. To compensate for this, we restricted our analysis to the 143 firms that entered the industry before 1976 and were not acquired. These are the only firms that could have survived for 20 or more years, and 17.5% did. In contrast, among the 53 spinoffs with parents that entered before 1976 and were not acquired, 32 or 60% of the spinoffs had parents that survived 20 or more years. Thus, it appears that longer-lived firms accounted for a disproportionate number of the spinoffs, consistent with the model.

The experiences of the longer-lived parents enabled us to gauge how firm spinoff rates varied with age over a wide range of ages. We divided the life of each of these firms into five-year intervals. They had the highest spinoff rate in the interval spanning ages 11 to 15, when they spawned 10 of their 32 spinoffs. Thus, there is some evidence supporting the conjecture that older firms had higher spinoff rates. However, only two of the 32 spinoffs occurred after the firms had survived 20 years, suggesting a downturn in the spinoff rate of firms after they passed a certain age. This will be explored further in the statistical analysis.

The timing of spinoffs in each market provides insight into the effects of market conditions on spinoffs. For most of the laser types, spinoffs were nearly uniformly distributed over time even though the entry of other firms varied considerably, suggesting that spinoffs were not particularly responsive to market conditions, as conjectured. The two lasers with a distinctive spinoff entry pattern were HeNe and ion, which were the most advanced along the product life cycle. In the last 10 years, there were no spinoffs in either laser. The only other laser with any sign of a decline over time in the number of spinoffs was CO2, which did not experience any spinoffs in its last five years. Thus, the evidence is consistent with the conjecture that firms producing types of lasers that were more advanced along the product life cycle had lower spinoff rates.

One geographic region stood out for spinoffs: northern California around Silicon Valley. It was the most densely populated region with 15% of the laser firms. Consistent with the conjecture about the density of firms and the ease of forming teams of founders, Silicon Valley accounted for a disproportionate number of spinoffs. Twenty-three, or 29%, of the spinoffs had parents located in the region, with 20 of the 23 spinoffs also locating there. None of the other three regions containing a sizable fraction of the firms accounted for a disproportionate number of spinoffs.

The tabulations we reported were intended to provide an overview of the more pronounced patterns characterizing the laser spinoffs. They were generally consistent with the various hypotheses, but statistical analysis is needed to probe the hypotheses more systematically.

5. Statistical Analysis

We estimated three logit models to test more comprehensively the predictions of the theory. In the first logit, the dependent variable \( P_i \) equals the probability that over its lifetime firm \( i \) spawned one or more spinoffs, and there is one observation for each of the 465 firms in the sample. We used this logit to explore the firm characteristics that were conducive to spinoffs. The explanatory variables include the total number of years the firm produced lasers, 1-0 dummies equal to 1 for firms that were acquired by laser and nonlaser firms respectively, a 1-0 dummy equal to 1 for preexisting entrants that had at least 10 patents in the five years prior to entry in lasers, and a 1-0 dummy equal to 1 for firms located in the most densely populated laser region, northern California around Silicon Valley. We also experimented using other firm characteristics, such as the background of the firm (preexisting, spinoff, university start-up, other kind of start-up), its age and industry if a preexisting entrant, and whether it was located in the next three most agglomerated regions, but none of these variables had sizable or significant effects in any of the logits. We also summed the total number of years of production across all lasers and used this with, and as a substitute for, the firm’s total years of production, but it was not significant with total years of production in the model and it performed worse than total years of production on its own. We also experimented using higher-order terms for total years of production, but none of them was significant.
The coefficient estimates for each explanatory variable are presented in the left column of Table 2. All the estimates are positive and all are significant at least at the 0.10 level except being located in Silicon Valley and being acquired by a laser firm, which are both included because of their performance in the other two logits. Not surprisingly, longer-lived firms were more likely to spawn spinoffs, no doubt because of their greater longevity as well as greater success. Firms that were acquired both by incumbent laser firms and nonlaser firms had higher spinoff rates. This generalizes Brittain and Freeman’s (1986) finding that semiconductor firms that were acquired by nonsemiconductor firms had higher spinoff rates. Preexisting firms that were more intense patenters had higher spinoff rates, which is consistent with such firms having greater technical knowledge for its employees to tap. Most of these firms were diversified electronics and chemical firms whose primary product was not lasers. As such, this result is opposite to Brittain and Freeman’s (1986) finding that semiconductor firms whose primary product was not semiconductors had lower spinoff rates.

In the second logit, each firm is considered as a potential parent of nine different types of spinoffs corresponding to each of the nine laser types. The

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient estimate (std. error)</th>
<th>Variable</th>
<th>Coefficient estimate (std. error)</th>
<th>Variable</th>
<th>Coefficient estimate (std. error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.505*** (0.464)</td>
<td>Constant</td>
<td>-8.242*** (0.888)</td>
<td>Constant</td>
<td>-11.333*** (1.711)</td>
</tr>
<tr>
<td>Years produced laser firm</td>
<td>0.107*** (0.032)</td>
<td>Produced laser k</td>
<td>2.484*** (0.488)</td>
<td>Current producer of laser k</td>
<td>2.263*** (0.703)</td>
</tr>
<tr>
<td>Acquired by laser firm</td>
<td>0.823 (0.583)</td>
<td>Years laser k</td>
<td>0.139*** (0.020)</td>
<td>Produced laser k</td>
<td>2.752*** (0.623)</td>
</tr>
<tr>
<td>Acquired by other firm</td>
<td>1.409** (0.558)</td>
<td>Acquired by laser firm</td>
<td>0.663* (0.362)</td>
<td>Produced laser k</td>
<td>1.569* (0.941)</td>
</tr>
<tr>
<td>10 or more patents</td>
<td>2.262*** (0.460)</td>
<td>Acquired by other firm</td>
<td>0.806** (0.342)</td>
<td>Prior years of laser k</td>
<td>0.348*** (0.094)</td>
</tr>
<tr>
<td>Silicon Valley firm</td>
<td>0.436 (0.500)</td>
<td>10 or more patents</td>
<td>1.707*** (0.292)</td>
<td>Prior years of laser k</td>
<td>-0.012*** (0.004)</td>
</tr>
<tr>
<td>N</td>
<td>465 (0.328)</td>
<td>Silicon Valley firm</td>
<td>0.594* (0.328)</td>
<td>Total years laser k</td>
<td>0.022 (0.020)</td>
</tr>
<tr>
<td>LogL</td>
<td>-102.489 (0.053)</td>
<td>N</td>
<td>4.185 (0.063)</td>
<td>Current laser producer</td>
<td>1.311 (0.993)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LogL</td>
<td>-214.288 (0.274)</td>
<td>Exit w/in 5 years</td>
<td>1.661* (0.863)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total years of laser production</td>
<td>0.016 (0.029)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acquired by laser firm</td>
<td>0.714* (0.385)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acquired by other firm</td>
<td>0.562 (0.358)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 or more patents</td>
<td>0.739*** (0.274)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 or more patents, did not produce laser k</td>
<td>2.227*** (0.635)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silicon Valley firm</td>
<td>0.598* (0.268)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>First 7 years of laser k</td>
<td>0.802*** (0.389)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Above average entry rate</td>
<td>0.569 (0.559)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Below average entry rate</td>
<td>4.382*** (1.718)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Age of HeNe market</td>
<td>-0.063 (0.053)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Age of ion market</td>
<td>-0.100* (0.057)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>58.893 (437.362)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LogL</td>
<td></td>
</tr>
</tbody>
</table>

*Significant 0.10; **Significant 0.05; ***Significant 0.01.
dependent variable is \( P_{ik} \), which is the probability that over its lifetime firm \( i \) spawned one or more spinoffs initially producing laser \( k \), and there are nine observations per firm for a total of 4,185 observations. We add two variables to the first logit to explore how experience in laser \( k \) versus general experience affected \( P_{ik} \). The first variable is a 1-0 dummy equal to 1 if firm \( i \) ever produced laser \( k \), and the second variable equals the total number of years firm \( i \) produced laser \( k \). We included all the other variables of logit 1, but the total number of years of laser production (or the sum of the total number of years of production of all other lasers than laser \( k \) had a trivial effect and was dropped from the final specification. The coefficient estimates are presented in the middle column of Table 2. All the estimates are positive and significant. Experience producing laser \( k \) greatly increased \( P_{ik} \): the odds ratio is 12 times higher for producers of laser \( k \) \( (e^{0.485} = 11.99) \) and 1.1 greater still for each year of production of laser \( k \). Consistent with the theoretical model, the probability of a firm spawning a spinoff initially producing a particular laser was a function of the firm’s experience producing that laser and not its general experience.

In the third logit, in each year beginning with its year of entry and extending through 1994, each firm is considered a potential parent of a spinoff initially producing any of the lasers being produced (by one or more firms) in the respective year. This allows for an (ex)employee starting a laser firm after its parent exited. The dependent variable \( P_{ik,t} \) is the probability of firm \( i \) spawning a spinoff initially producing laser \( k \) in year \( t \). There are many observations per firm and 58,893 observations in total.

The variables pertaining to production of laser \( k \) in the second logit can be broken down further to probe how a firm’s experience producing laser \( k \) affected \( P_{ik,t} \). Three mutually exclusive 1-0 dummies are used that equal 1 for firms producing laser \( k \) in year \( t \), for firms that ceased producing laser \( k \) within five years of year \( t \), and for firms that ceased producing laser \( k \) over five years before year \( t \). For firms producing laser \( k \) in year \( t \), the number of prior years it produced laser \( k \) and the square of this variable were added to probe how \( P_{ik,t} \) changed as the firm’s experience producing laser \( k \) increased. The total years of production of laser \( k \) was retained, but its interpretation is now different. It tests whether firms that were more successful at producing laser \( k \), as proxied by their total years producing laser \( k \), had higher probabilities of spawning a spinoff initially producing laser \( k \) at every point in their history (i.e., at each year of production of laser \( k \)).

\[ \text{Success} = \text{proxyed by the total years a firm produced a particular laser. If a firm was still producing a laser and was acquired added to probe the role of general experience. The first two are 1-0 dummies equal to 1 if the firm was a current laser producer in year \( t \) or if it had ceased producing lasers within five years of year \( t \) (exiting over five years ago was the omitted category). The other variable is the total number of years the firm produced lasers through year \( t \) if it was still producing lasers in year \( t \) (otherwise it equals 0).} \]

The two acquisition dummy variables were retained but were restricted to equal 1 if the respective acquisition occurred up to two years after year \( t \) and five years before year \( t \). Many of the acquisitions were reported in the trade press before they were consummated, so this variable was allowed to take on a value of 1 for up to two years prior to the official consummation of the acquisition. The variable for diversifying firms of having at least 10 patents was retained, and it was also entered again as a separate variable for firms that never (commercially) produced laser \( k \). Many of the intense patenters worked for the military but did not commercialize all the lasers they worked on for the military, which may have provided their employees with distinctive opportunities to start their own firms. If having at least 10 patents is a proxy for knowledge, then it should continue to have a positive coefficient estimate, but if intense patenters that never commercially produced laser \( k \) provided distinctive opportunities for their employees to do so, then the coefficient estimate of 10 or more patents for firms that never produced laser \( k \) should also be positive. The variable for being located in Silicon Valley was also retained, unmodified, from the second logit.

Last, we included a set of variables to probe how market conditions affected spinoffs. We constructed a variable measuring the rate of entry into market \( k \) in year \( t \) of firms other than spinoffs to probe how spinoffs are conditioned by the factors generally by another laser firm, then its years of production are censored. Similarly, if a firm produced a laser through 1994, then its years of production are also censored. In both cases, the total years of production understates the firm’s performance. This will introduce measurement error, which generally contributes to attenuated estimates. To address this, we added a dummy for censored firms. If the additional number of years these firms would have produced laser \( k \) (if not censored) is independent of their past years of production of laser \( k \), the coefficient on the dummy should equal the coefficient on the total number of years laser \( k \) was produced times the expected additional years of production of laser \( k \). However, the coefficient estimate for the dummy was trivial and insignificant. This may reflect that censored firms with a longer history of production of laser \( k \) would be expected to produce it for more additional years than firms with a shorter history of production of laser \( k \) and/or acquired firms. Both possibilities make the need for a censoring correction less compelling.

\[ We also experimented by adding the square of the total years the firm produced laser \( k \) and the total number of years the firm ever produced lasers, but the effects of both were trivial and insignificant. \]
affecting entry. This variable equals the number of entrants other than spinoffs in market \( k \) in year \( t \) divided by the number of firms producing laser \( k \) in year \( t - 1 \) plus two lagged values of this variable (for smoothing purposes), expressed as a deviation from the mean value of this variable for market \( k \) across all years. To avoid very large values of this variable in the early years of markets when the number of producers is very small, we set it equal to 0 in the first seven years of a market. We also included a 1-0 dummy variable equal to 1 for the first seven years of market \( k \). This allows for spinoffs to capitalize on the experience their parents gained producing or researching laser \( k \) for themselves or the military but not commercially, which tended to occur in the early years of the various laser types. We divided the entry variable according to whether it was above or below its mean to test for an asymmetric effect of favorable and adverse market conditions on spinoffs, as predicted by the model. We entered linear time trends for the age of the HeNe and ion markets to test for a decline in the probability of spinoffs over time in these markets due to progressing further along the product life cycle.\(^20\) We also included fixed effects for the different types of lasers.

We estimated the model unconditionally and conditionally using the approach developed by Chamberlain (1980) to handle firm fixed effects in logits. In the Chamberlain approach, the likelihood of each observation for a firm is expressed conditional on the total number of spinoffs of the firm. The coefficient estimates then reflect the factors influencing the years and markets in which each firm’s spinoffs were concentrated. This procedure requires dropping the observations of firms with no spinoffs and the variables that do not vary across the observations for each firm (being located in Silicon Valley and having 10 or more patents). A Hausman test comparing the Chamberlain coefficient estimates with those based on ordinary logit estimation on the reduced sample and variable set (cf. Greene 1993, p. 657) could not reject the null hypothesis of the firm fixed effects equaling zero (the \( p \)-value of the chi-squared statistic was 0.5737). Accordingly, only the ordinary logit coefficient estimates estimated on all the observations and variables are reported.

The coefficient estimates and standard errors are presented in the right column of Table 2. All three period dummies for the production of laser \( k \) are positive and significant. Not surprisingly, firms are more likely to spawn a spinoff producing a particular laser if they produced the laser as well. The coefficient estimate for having ceased production of laser \( k \) within the last five years is not much greater than the coefficient estimate for being a current producer of laser \( k \), which calibrates the probability of a firm spawning a spinoff initially producing laser \( k \) when it first began producing laser \( k \). The coefficient estimate for having ceased producing laser \( k \) over five years ago is smaller than the other two but still substantial. It implies that the effect of production of laser \( k \) on the rate of spinoffs initially producing laser \( k \) declines over time after production of laser \( k \) ceases but persists for many years. The coefficient estimates of the linear and quadratic terms for prior years of production of laser \( k \) are positive and negative, respectively, and both are significant at the 0.01 level. The estimates imply that the probability of a spinoff initially producing laser \( k \) at first rises, as conjectured, but then it peaks at 14 years of experience producing laser \( k \), after which it declines. At 14 years of experience, the odds ratio is 11.4 times greater than initially, and it declines back to its initial value after 28 years of experience, which very few firms attained in any laser.\(^21\) Thus, middle age appears to be the most fertile period for firms to spawn spinoffs. The coefficient of the total years of production of laser \( k \) is positive but its standard error is sufficiently large that it falls short of significance at the 0.10 level. Consistent with the model, it suggests that the firm’s success producing laser \( k \) may increase the probability of it spawning a spinoff initially producing laser \( k \) in every year, but the crudeness of the measure limits the confidence one can have in such an inference.

The coefficient estimate of the main variable for general experience, total years of production, is trivial and insignificant. Similar to the second logit, \( P_{kl} \), is influenced only by a firm’s years of experience producing laser \( k \) and not its general years of experience. The period dummies indicate that the probability of a firm spawning a spinoff initially producing laser \( k \) is similar for both current laser producers and firms within five years of exiting the industry, but falls after a firm has not produced lasers for over five years. This may reflect that after five years, employees of the firm that have not started their own firm either have found employment with another laser firm or have left the industry, diminishing the chance of them starting a laser spinoff (attributed to their initial employer). This appears to be the only way general experience enters into the spinoff process.

Three of the four firm variables have significant effects, with the fourth close to significant at the 0.10

\(^20\) We also entered a linear time trend for spinoffs in all laser types, but it was not included in the final specification because its effect was small and insignificant.

\(^21\) It is still greater at this point than firms that never produced laser \( k \), and thus additional years of experience in laser \( k \) continue to increase the firm’s cumulative probability of spinoffs initially producing laser \( k \).
level. Both types of acquisitions increase the spinoff rate, with the effect of acquisitions by laser firms slightly greater than that for acquisitions by nonlaser firms. Being located in the Silicon Valley area significantly increases the probability of a spinoff. The coefficient estimate of having 10 or more patents is positive and significant, supporting its interpretation as a proxy for knowledge available for employees to exploit. The coefficient estimate of this variable for firms not producing laser $k$ is also positive and significant, suggesting that this knowledge was particularly valuable for employees to exploit if their employer did not produce laser $k$. This would be consistent with some of these nonproducers of laser $k$ working for the military researching or producing laser $k$, which would have provided their employees distinctive opportunities to start their own firm producing laser $k$.

The final set of estimates pertain to the market variables, and these are all as predicted. The coefficient estimate for the first seven years of a laser market is positive and significant, indicating a higher spinoff rate in the early years of markets than expected based on firms’ limited experiences in the markets. The coefficient estimate for entry rates above the mean is positive but small and insignificant, whereas the coefficient estimate for entry rates below the mean is positive, large, and significant. This supports the asymmetric effect of market conditions on the spinoff rate predicted by the model. The HeNe and ion time trends are both negative, with the ion coefficient estimate significant at the 0.10 level. Thus, spinoff rates fell off faster in the two laser markets that were furthest advanced along the product life cycle.

6. Discussion

We developed a simple model to explain the regular occurrence of spinoffs and used the model to guide the analysis of spinoffs in the laser industry. Our findings amplify and expand on the findings about spinoffs in other industries, most notably semiconductors (Brittain and Freeman 1986) and disk drives (Franco and Filson 2000, Agarwal et al. 2004). Our objective in this section is to summarize the findings in a way that transcends the specifics of the model. The findings can then be used as targets to guide further theorizing and empirical work. We exploit the core idea of the model that firms can be thought of as giving birth to spinoffs, so that spinoffs have parents from whom they inherit specific traits, in this case knowledge. We use this and other evolutionary ideas to synthesize and interpret the findings.

The probability of a firm spawning a spinoff producing a particular laser was related primarily to the firm’s experience producing the laser and not its general experience. Nearly all the spinoffs also produced lasers their parents produced. This suggests that spinoffs exploited targeted knowledge from their parents. The qualitative evidence suggested that spinoffs initially serviced narrow, targeted niches that overlapped with their parents’ markets but over time they also serviced related but different markets than their parents. They generally did not compromise the viability of their parents’ related markets, possibly because of the modesty of their initial efforts and the extent to which they differentiated themselves.

Spinoffs were heavily concentrated among longer-lived firms, and the probability of a firm spawning a spinoff producing a particular laser was an increasing function of the firm’s total experience producing the laser. Presuming that longer-lived firms generated greater knowledge, this suggests that spinoffs were more likely in environments in which employees had more knowledge to draw on. Spinoffs were most likely when firms reached middle age. The initial rise in the spinoff rate with age may reflect a growing knowledge for employees to exploit. The later decline with age is more puzzling. We speculate about this below.

Within each laser submarket, spinoffs were responsive to adverse but not favorable conditions for entry. Thus, they could be discouraged by unfavorable market conditions but did not appear to depend on favorable market conditions to be able to enter. In two submarkets that had progressed furthest along the product life cycle, the probability of spinoffs declined over time. This may reflect a change in the kind of information firms generated that compromised the knowledge available for employees to exploit.

Acquisitions of firms increased the chance of spinoffs, possibly by increasing the probability of management not perceiving opportunities generated by the firm’s past R&D. Preexisting firms with a greater technical orientation as reflected in their prior patenting had more spinoffs. This appears to have been related both to the greater knowledge they generated for spinoffs to exploit and their reluctance at times to commercialize work they performed for the military, providing a bigger market for their spinoffs to capture. Firms located in northern California around Silicon Valley had higher spinoff rates, which may well have been due to the greater ability to form founding and initial management teams from

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A positive (and significant) coefficient estimate for entry rates below the mean implies that the entry rate of spinoffs and other firms is positively correlated for below average rates of entry of other firms, which is consistent with the prediction of the model that unfavorable demand conditions will depress entry by spinoffs. The fact that the coefficient estimate for entry rates above the mean is positive but smaller and not significant is consistent with the prediction of the model that favorable demand conditions will have less effect on spinoff entry than unfavorable demand conditions.
the wealth of laser and nonlaser talent in Silicon Valley.23

These findings not only have implications about spinoffs but also for evolution and organizational behavior, the determinants of entry and the evolution of market structure, and technological change and industry performance. We began the paper by discussing the parallels that have usefully been drawn between natural evolution and industrial competition, particularly using the metaphors of variation and selection so central to evolutionary theories. Our findings suggest that the less-used evolutionary notions of birth and heredity may have comparably useful roles in understanding spinoffs. Spinoffs appear to closely resemble their parents, inheriting from them their initial products and market focus. But just as organisms are not clones of any of their parents, spinoffs also differed from their parents. Perhaps similar to humans, spinoffs needed to differentiate themselves from their parents to succeed. Pushing the evolutionary metaphor further, more fit members of the species (industry) have higher rates of reproduction, which as we discuss below bears on the fitness of the entire species.

Perhaps the most significant implication of harnessing the notions of birth and heredity to spinoffs is that it strengthens the idea of organizations with distinctive, and limited, capabilities. This is a long-standing theme in the literatures of business strategy and organizations. Our findings provide a clearer picture of the origin of these capabilities for one class of organizations, spinoffs. They also provide insights into the limits of organizations. Judging from the similarities between spinoffs and their parents, organizations need targeted technical and market information to be able to compete in particular markets, and this information is difficult to come by. This suggests that in developing a business strategy, organizations, especially new organizations, need to think carefully about the information they have access to and how they can profit from it.24 Firms will generally have limited options, which in turn will limit the value of industry analyses designed to identify attractive venues to enter.

Our findings regarding the initial strategies of spinoffs resonate with Bhide’s (2000, pp. 29–68) findings about the initial strategies of successful startups. Both started out with limited knowledge and modest strategies. The initial success of Bhide’s startups depended on their ability to exploit unexpected opportunities. Their continued success depended on their ability to transform themselves as they grew to take advantage of their greater size, which enabled them to take on more capital intensive projects with more predictable outcomes. To the extent this resulted in them generating knowledge that became more embodied in physical than human capital, it may help explain our findings concerning the effect of a firm’s experience on its rate of spinoffs. Inexperienced firms would not have much knowledge to draw on, whereas successful firms presumably would have more knowledge for spinoffs to exploit. But if successful firms changed their strategy as they grew and aged, causing the character of their knowledge to become more embodied in physical capital, then employees might have had more difficulty accessing the firm’s key knowledge. In effect, organizations would go through a comparable evolution to the product life cycle operating at the market level (cf. Miller and Friesen 1984, Kazanjian and Drazin 1989), which could explain the nonmonotonic effect of experience on the spinoff probability that we found. This deserves further exploration.

Our findings also provide insight into the entry process. The conventional economic view of entry is that it is a response to incumbents earning high profits. However, Geroski (1995) notes that this view has been quite limited in its ability to explain variations in entry across markets and within markets over time. These limitations are palpable for our laser spinoffs, which constituted over 15% of the entrants into the laser industry. They do not appear to have been responsive to the factors favoring entry of other types of firms. Our findings suggest why—spinoffs are mainly tied to the experiences of incumbent producers rather than the prospects for new producers. As long as demand conditions are not unfavorable, they enter when their parents generate the information they need to exploit, which tends to be when their parents reach laser middle age. The turnover among laser producers has contributed to a fairly steady stream of new firms and thus new candidates for laser middle age, contributing to a steady stream of spinoffs. Their timing is determined principally by their parents and not the market, although it is not hard to envision how they could be discouraged by adverse developments, as we found.

Our findings regarding the decline in the spinoff rate in the HeNe and ion submarkets also suggest how distinctive market conditions not directly related

23 An alternative explanation is that it reflects restrictions in California on the enforcement of noncompete covenants (cf. Stuart and Sorenson 2003). This suggests that firms located in any part of California should have had higher spinoff rates. However, as noted earlier, when a dummy was entered in all three logits for firms located in southern California (dummies were also entered for firms in the New York and Boston areas, the next two most agglomerated areas after northern and southern California), the coefficient estimate of the dummy was trivial and insignificant.

24 Holbrook et al. (2000) reach the same conclusion about preexisting firms as well as start-ups in a detailed examination of four early entrants into the semiconductor industry.
to the profitability of incumbents could influence entry. To the extent markets evolve according to the product life cycle, opportunities for spinoff entry may dry up, causing the overall rate of entry to decline. This can have far-reaching implications regarding an industry’s market structure. In lasers, the steady stream of spinoffs has no doubt contributed to the turnover in producers and limited the concentration of producers. Should more submarkets evolve according to the product life cycle with greater attention devoted to improving the production process, however, it could lead to less spinoffs and greater market concentration (cf. Klepper 1996, 2002a). Indeed, a distinguishing feature of the four industries studied by Klepper and Simons (1997) that experienced sharp shakeouts and evolved to oligopolies is that producers devoted great effort to improving the production process. Turned around, this implies that an important reason the laser industry has not become very concentrated is that significant opportunities to improve the production process have so far been limited to only a few lasers. Why this is so deserves further investigation.

Finally, our findings have implications about the private and social consequences of spinoffs, particularly as they bear on technological change. Spinoffs are often characterized as exploiting discoveries their founders worked on in their prior employer (cf. Anton and Yao 1995). Many parents perceive spinoffs as predators that steal their ideas and innovations. Intel epitomizes this attitude. It is willing to go to great lengths to discourage spinoffs, including harrassing them with legal suits (Jackson 1998, pp. 211–338). Not only does this result in socially wasteful expenditures, but the prospect of spinoffs could even discourage firms from undertaking innovations that employees could appropriate within their own firms. Alternatively, much of the empirical scholarship on spinoffs is preoccupied with their prowess at innovation. They are often perceived as overcoming the bureaucratic inertia plaguing established companies.

Our findings provide some insight into this debate. Our model indicates that spinoffs can be rationalized without appealing to some kind of bureaucratic inertia plaguing incumbent firms. They have an incentive to pursue ideas that their parents would not because it would cannibalize their parents’ market. This is not necessarily socially productive. However, we can use another analogy to natural evolution to speculate on how spinoffs can be socially beneficial. An organism’s behavior is determined not only by its genes but also by its environment. Similarly, once “born,” a spinoff’s activities will evolve in unpredictable ways. In evolutionary terms, this provides the basis for diversity, which in the context of innovative industries like lasers means diversity in the kind of innovations firms develop. Many evolutionary theories emphasize the importance of diversity. Relatedly, Nelson (1981, 1990) has stressed the critical role diversity plays in the success of capitalism, while Cohen and Klepper (1992) and Klepper (1996) theorize about how a decline in diversity can retard an industry’s rate of technological change. Interpreted in this light, spinoffs can be quite beneficial socially.

The laser industry provides a forum to evaluate these arguments. While we found instances of spinoffs commercializing ideas that established firms chose not to pursue, we found few instances of spinoffs appropriating the ideas or innovations of their parents. Spinoffs appear to have engaged in a range of activities to differentiate their lasers from those of their parents. Many introduced important innovations over their lifetimes and became very successful. This was true of a number of the firms featured in Table 1 and also many of the leading U.S. firms, including the two industry leaders, Spectra Physics and Coherent. Clearly, many of the spinoffs brought distinctive abilities to the industry that no doubt advanced the industry’s rate of technological change. Agglomeration of producers, in this case around Silicon Valley, also appears to have increased firm spinoff rates, which would confer further social benefits if spinoffs are indeed socially beneficial.

In conclusion, the perspective of spinoffs being descended from their parents provides a useful way of exploiting many of the concepts that have been productively employed in theories of natural evolution. It yields insight into organizational behavior, business strategy, entry and industry evolution, and technological change. Understanding the lineage of not only spinoffs but other types of entrants may yield further insight into an even broader array of important issues concerning industrial competition and technological change.

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