

Disagreements and Intra-industry Spinoffs

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A growing empirical literature on spinoff formation has begun to reveal some striking regularities about which firms are most likely to spawn spinoffs, when they are most likely to spawn them, and the relationship between the quality of the parent firm and its spinoffs. Deeper investigations into the causes of spinoffs have highlighted the importance of strategic disagreements in driving some employees to resign and found a new venture. Motivated by this literature, we construct a new theory of spinoff formation driven by strategic disagreements, and explore how well it explains the emerging empirical regularities.

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I. Introduction

In recent years various studies have traced the origins of entrants in innovative new industries in the U.S. and elsewhere in order to understand how the backgrounds of entrants influences their performance. In industry after industry, one class of entrants has stood out: firms founded by employees of incumbent firms in the same industry. We call these firms intra-industry spinoffs. In many innovative industries, both old and modern, upwards of 20% of the entrants are intra-industry spinoffs, and these firms consistently outperform other *de novo* entrants and disproportionately populate the ranks of the industry's leaders (Sleeper [1998], Klepper [2002], Agarwal et al. [2004], Thompson [2005], Boschma and Wenting [2007], Buenstorf [2007], Buenstorf and Klepper [2007], Roberts et al. [2007], von Rhein [2008], Chatterji [2008]). Various regularities concerning the firms most likely to spawn intra-industry spinoffs, the circumstances that are conducive to such spinoffs, and the relationship between the performance of intra-industry spinoffs and their parents are also starting to accumulate.

The prominence and distinctive performance of intra-industry spinoffs raises fundamental theoretical and policy-related questions. What defines a firm's activities versus the kinds of activities a firm's employees pursue in their own startups? Are incumbent firms systematically missing out on good opportunities or are firms limited in the number of projects they can pursue and/or in their ability to protect their intellectual property? Should legal policies, such as the enforcement of employee non-compete covenants, be loosened to encourage intra-industry spinoffs or tightened to discourage them? Answers to these questions hinge on understanding why employees leave established firms to start firms in the same industry and on the forces governing the occurrence of intra-industry spinoffs.

Theories proposed to account for spinoffs tend to fall into three camps. In the first, an employee makes a serendipitous discovery of some economic value. The discovery is in principle more valuable to the incumbent firm than it would be to a startup, but information asymmetries of one form or another persuade the employee to implement the discovery through his own startup rather than reveal it to his employer.¹ In the second type of model, the discovery

¹ See Anton and Yao [1995], Wiggins [1995], Bankman and Gilson [1999], Gromb and Scharfstein [2002], Amador and Landier [2003], and Hellman [2007]. Common themes are: i) firms cannot commit to a contingent contract that adequately rewards the employee for his discovery and the subsequent employee effort needed to implement it; and (ii) non-contingent contracts that are *ex ante* acceptable to the firm will not always be sufficient to prevent a departure by the employee.

is common knowledge within the firm but is less valuable to the incumbent than it would be to a start-up, because its implementation would cannibalize existing rents or because the firm has limited competence to evaluate the idea, particularly when the idea is tangential to the firm's main activities.² In the third type of model, employees learn from their employers about how to profitably compete in their industry, especially when their employer is successful. They exploit this knowledge by setting up their own firm in the same industry.³ We assemble mini-case studies that have been developed for the leading intra-industry spinoffs in three industries, the historical automobile and the modern semiconductor and laser industries, to gain insight into the reasons spinoffs occur. The evidence points to a phenomenon not captured by existing theories: disagreements among leading decision makers concerning fundamental ideas about technology and management that prompt dissidents to leave and start their own firms.

The management literature stresses the importance of firms forging a consensus about their strategy (e.g., Cyert and March [1963], Andrews [1971], Dess and Priem [1995]). With the exception of some recent work by Van den Steen [2004, 2005, 2006], however, few attempts have been made to model the formation of a consensus and the emergence and consequence of disagreements among members of management teams. The primary goal of our paper is to construct a model of spinoffs based on the idea of disagreements consistent with our case study evidence and to explore its consistency with the empirical regularities that have been accumulating about intra-industry spinoffs.

In our model, firms are formed of like-minded individuals and then employees get different signals about the best strategic direction for their firm. They communicate their signals to each other, which causes their views to converge. However, inevitably decision makers in some firms have difficulty evaluating the ideas that employees propose, which can lead to the underweighting of good ideas and to disagreements. If others outside the firm are better able to evaluate the ideas and the ideas are sufficiently worthwhile to justify the costs of starting a new firm, then a spinoff will be formed.

The paper is organized as follows. In Section II we lay out the main findings that have been accumulating from recent empirical studies of intra-industry spinoffs. In Section III we examine the role of internal disagreements in the formation of intra-industry spinoffs in automo-

² See Pakes and Nitzan [1983], Tushman and Anderson [1986], Henderson and Clark [1990], Christensen [1993], Klepper and Sleeper [2005], and Cassiman and Ueda [2006].

³ See Agarwal et al. [2004] and Franco and Filson [2006].

biles, semiconductors, and lasers. In Section IV we present our model and derive its implications for the timing of spinoffs, their performance, and the performance of their parents. In Section V we discuss some normative implications of our theory.

II. Empirical Regularities

Most of the studies of intra-industry spinoffs examine U.S. manufacturing industries during their first 30 to 35 years when entry is greatest, including automobiles (Klepper [2007a, 2007b]), tires (Buenstorf and Klepper [2007]), semiconductors (Brittain and Freeman [1986], Klepper [2007c]), disk drives (Agarwal et al. [2004], Franco and Filson [2006]), lasers (Sleeper [1998], Klepper and Sleeper [2005], Sherer [2006]), medical devices (Chatterji [2008]), and biotechnology (Mitton [1990], Stuart and Sorenson [2003]). A few parallel studies have been conducted for automobiles in Great Britain (Boschma and Wenting [2007]) and automobiles (von Rhein [2008]) and lasers (Buenstorf [2007]) in Germany. Intra-industry spinoffs have also been studied in U.S. law firms (Phillips [2002]) and Australian and New Zealand wine producers (Roberts et al. [2007]). The main focus of these studies is on the rate at which firms spawn intra-industry spinoffs and the performance of the spinoffs. Also touched on is the extent to which knowledge is transferred from “parents” to spinoffs. Similar issues were examined in a recent study (Eriksson and Kuhn [2006]) of all spinoffs across the entire Danish private sector.⁴

As the number of studies of intra-industry spinoffs accumulate, it is possible to identify a number of common findings across industries. Five patterns show up consistently in all or most of the industries where they have been studied, both in the U.S. and elsewhere. First, in autos, tires, semiconductors, disk drives, and lasers, better-performing firms, measured by longevity, peak market share, early entry, product quality and/or product scope, have higher intra-industry spinoff rates.^{5,6} Second, in autos, biotechnology, lasers, and semiconductors,

⁴ Another broad study that covers somewhat different issues examines the rate at which publicly traded firms spawned VC-financed spinoffs (Gompers et al. [2005]).

⁵ In the U.S. laser industry, however, the rate at which firms spawned spinoffs initially producing a particular type of laser was unrelated to the firm’s performance in that laser type, proxied by the total number of years it produced the laser (Klepper and Sleeper [2005]).

⁶ These findings could merely be due to better firms being larger and thus having more employees that could potentially found firms. Agarwal et al. [2004] and Franco and Filson [2006] test this idea in disk drives using the number of disk drives produced as a measure of firm size. They find that even after controlling for firm size, the quality of a firm’s technology and whether it entered

firms acquired by non-industry incumbents have higher intra-industry spinoff rates around the time of their acquisition, while in autos and lasers (but not biotechnology or semiconductors) firms acquired by industry incumbents also have comparably higher intra-industry spinoff rates around the time of their acquisition. Relatedly, in semiconductors firms that hired a CEO from outside the company have higher intra-industry spinoff rates, which accords with findings from the Danish study that spinoffs are more likely in firms whose CEO has recently changed. Third, in autos, lasers, semiconductors, and law firms (but not disk drives or tires), the rate at which firms spawn intra-industry spinoffs tends to rise through about age 14. While most firms exit by age 14, among those that continue the spinoff rate tends to fall as they age further.⁷ Fourth, in autos, disk drives, lasers, medical devices, tires, and wine, the performance of intra-industry spinoffs⁸ is superior to other *de novo* entrants and is comparable if not superior to diversifiers from related industries. Similarly, in the Danish study spinoffs that are formed for positive reasons (i.e., not due to the parent exiting in the year of the spinoff) and that are in the same industry as their parent (i.e., intra-industry spinoffs) survive longer than other new entrants. Fifth, in autos, tires, semiconductors, disk drives, and law firms (but not lasers), the better the performance of parent firms⁹ then the better the performance of their intra-industry spinoffs.¹⁰

The five regularities are summarized in Table 1 in the order they will be addressed in the discussion of the theoretical model.

earlier into the production of new disk drives both positively affect the firm spinoff rate (in Agarwal et al. [2004] size also positively affects the firm spinoff rate whereas in Franco and Filson [2006] it negatively, but insignificantly, affects the firm spinoff rate).

⁷ Mitton's [1990] evidence indicates that among biotechnology firms in San Diego, the spinoff rate increased through age 10, consistent with the patterns found in autos, lasers, and law firms. There were no firms in his sample older than age 10, however, to judge whether spinoff rates declined at older ages.

⁸ Based on longevity, peak market share, scope, years to first VC funding, or pre-money valuation.

⁹ Based on longevity, market share, and/or quality of technology.

¹⁰ In disk drives, Agarwal et al. [2004] found that firms with better technology had spinoffs with better technology, and firms (of all types) with better technology survived longer. However, in a direct analysis of the relationship between spinoff longevity and characteristics of parents, Franco and Filson [2006] did not find that spinoffs from parents with better technology survived longer (if anything, they survived shorter).

TABLE 1. Intra-industry Spinoff Regularities

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- A The probability of an intra-industry spinoff first rises and then falls with firm age, making middle age the most likely time for intra-industry spinoffs.
 - B Firms that are acquired have a higher rate of intra-industry spinoffs around the time of their acquisition, particularly when they are acquired by firms in other industries. A change in the firm’s CEO, particularly from outside the firm, similarly increases the rate of intra-industry spinoffs.
 - C Better-performing firms spawn intra-industry spinoffs at a higher rate.
 - D Better-performing firms have better-performing intra-industry spinoffs.
 - E Intra-industry spinoffs perform better than other *de novo* entrants and comparably if not better than diversifying entrants.
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III. Spinoffs and Disagreements

The statistical regularities provide indirect evidence about the impetus for intra-industry spinoffs. In this section we present more direct evidence about the impetus for prominent intra-industry spinoffs in the historical automobile industry and the modern semiconductor and laser industries. These mini-case studies are based on historical accounts and testimony of the founders of the spinoffs presented in Klepper [2007a, 2007c], Klepper and Sleeper [2005], and Sherer [2006].

A. Automobiles

Consistent with the statistical regularities, the four firms that spawned the most spinoffs and accounted for many of the leaders of the industry, Olds Motor Works, Cadillac, Ford, and Buick (which evolved into General Motors), were four of the leading firms in the industry. Table 2 summarizes information for the leading spinoffs of these firms in terms of their year of entry, parent firm, impetus for their formation, prior position of their principal founder (in the parent firm), and their main source of finance based on Klepper [2007a].

Olds Motor Works had seven spinoffs, equaled only by Buick/GM, and in a more condensed time period than Buick, reflecting its limited life as an independent firm. Before its entry into automobiles, Olds was a successful engine producer headed by Ransom Olds, the son of

its founder. Olds introduced the first great car in the industry, the one-cylinder Curved Dash Runabout. To finance its entry into automobiles, Ransom Olds had to give up control of his company to Samuel Smith, a wealthy businessman with little experience in manufacturing. All but the first spinoff of Olds Motor Works occurred after Ransom Olds clashed with Samuel Smith and his son over whether to produce larger cars and whether to improve the manufacturing process to lower production defects. The clash resulted in Ransom Olds being forced out of the firm in 1904 when it was at its peak. Subsequently, he founded Reo with support from some of the other stockholders that had helped finance his entry into autos. Two years later the head of sales, Roy Chapin, and the chief engineer, Howard Coffin, left Olds Motor Works to found E.R. Thomas-Detroit with support from E.R. Thomas, who himself was a producer of a high-price car in a company bearing his name. They proposed a new four-cylinder car that was a compromise between the one-cylinder Curved Dash Runabout and the larger cars favored by the Smiths and left Olds when the Smiths withdrew support for the car at the last minute. Three years later two other top Olds employees, with support from one of their relatives, Joseph Hudson, a department store owner, formed Hudson with Chapin and Coffin to produce a new, low-priced four cylinder car that was designed by Coffin to compete with the newly introduced Model T. Chapin and Coffin had gotten Hugh Chalmers, a well-known marketing executive at NCR, to buy half of E.R. Thomas' stock in E.R. Thomas-Detroit to dilute his control over the company. Chalmers was not used to such major changes in his product and let the new car be developed in a separate company in which initially he took stock but then traded it for shares in his own firm. By this time Olds Motor Works had fallen out of the ranks of the leading firms under the Smiths' direction and had been rescued by the newly formed General Motors, which acquired it in 1908.

With the exception of Hupp, the other leading spinoffs in Table 2 were also born out of disagreements in their parent firm. Both of Cadillac's leading spinoffs involved Alanson Brush, a talented engineer-inventor that left Cadillac after a clash with the head of the firm over the use of his patents. Brush Runabout was subsequently formed by Brush and Frank Briscoe, one of Olds' initial subcontractors, to produce a new small car that Brush designed to test out some of the ideas he had developed at Cadillac. In the same year, Brush was also involved in the formation of Oakland with Edward Murphy, the owner of a successful carriage company that was impressed with the Brush Runabout and asked Brush to design a car for him. Both companies were soon acquired. Brothers John and Horace Dodge had been the primary producers of Ford's cars from the outset and held 10% of Ford's stock. They left Ford to found their own firm, Dodge Brothers, with their own funds when they felt threatened by Henry Ford's continual efforts to integrate backwards and Ford dawdled on their

TABLE 2: Leading Automobile Spinoffs

FIRM (PARENT)	YEAR	IMPETUS	POSITION	FINANCE
Reo (Olds)	1904	Management dispute	Head	Past stockholders
E. R. Thomas-Detroit (Olds)	1906	Proposed car rejected	Sales manager, Chief engineer	Auto man
Hudson (Olds & E. R. Thomas-Detroit)	1909	Proposed car rejected	Sales manager, Chief engineer	Relative
Brush (Caddy)	1907	Dispute over patents	Top engineer	Auto man
Oakland (Caddy)	1907	Dispute over patents	Top engineer	Carriage man
Hupp (Ford)	1909	Entrepreneur	Asst. Supt.	Minimal
Dodge Bros. (Ford)	1914	Rejected buyout	Producers, Stockholders	Self
Chevrolet (GM)	1911	Management dispute	Head	Self
Durant (GM)	1921	Management dispute	Head	Past stockholders

proposal to buy them out. Both of Buick/GM's leading spinoffs were founded by William Durant, who had catapulted Buick to success and subsequently organized General Motors (GM) with Buick as its centerpiece. Twice Durant was ousted from GM after failing to integrate the many acquisitions he engineered and GM floundered. The first time he organized Chevrolet and two other firms with his own funds and concentrated on producing a small car to compete with the Model T based on efforts he had initiated at Buick that were abandoned by the bankers that took over the management of GM after his ouster. His later startup, Durant Motors, was financed primarily by prior investors in Durant's ventures. Although initially successful, an unwise acquisition and expansion into a full range of cars ultimately doomed it.

B. Semiconductors

Silicon Valley is famous for spinoffs in the semiconductor industry. Table 3 summarizes in-

formation on the leading Silicon Valley spinoffs through 1986 based on Klepper [2007c]. Consistent with the statistical regularities, six of the leading spinoffs came out of Fairchild Semiconductor, which was the first great Silicon Valley firm that accounted for an extraordinary total of 24 spinoffs. Two of the other leading spinoffs came out of National and Intel, which themselves were leading spinoffs of Fairchild that accounted for the next most semiconductor spinoffs with nine and six respectively.

Similar to Olds, Fairchild was racked by internal turmoil that precipitated many of its spinoffs and eventually led to its decline. Fairchild itself was the byproduct of a disagreement at its parent firm, which led eight of its top employees to form Fairchild in 1957 with support from a Long Island defense contractor that subsequently exercised its right to purchase the firm. Fairchild Semiconductor co-invented and pioneered the integrated circuit (IC) and became the leader of the industry along with Texas Instruments. However, when its head of research, Gordon Moore, did not recognize the full potential of ICs, two groups of founders and top employees left to form Amelco and Signetics with support from downstream firms. Subsequently Fairchild was racked by internal problems related to the separation of R&D and manufacturing and control by a distant owner. National was formed in 1967 by the head of production, Charles Sporek, who was frustrated by lack of recognition and meager stock options from the parent company. Tensions involving the parent company and the inability of Fairchild Semiconductor to commercialize new products led Moore and Robert Noyce, the head of Fairchild Semiconductor, to depart in 1968 to found Intel. One year later the head of marketing, Jerry Sanders, left to found AMD after he clashed with Lester Hogan, who had been brought in from Motorola to turn around Fairchild. Many years later, the head of Fairchild, Wilf Corrigan, left to form LSI Logic with venture capital support after Fairchild was acquired by a non-semiconductor firm whose direction he disagreed with. This was the culmination of a long decline that eventually led to Fairchild's demise as an independent semiconductor producer in 1987.

Many of the other leading spinoffs involved strategic disagreements. Linear Technologies emerged out of National and Cypress Semiconductor out of AMD over divergent views about the potential of analog devices and Complementary Metal Oxide Semiconductors respectively. Both firms were financed by venture capitalists. Similar to AMD and LSI Logic, other leading spinoffs resulted from tensions that arose as the result of an acquisition or when a new CEO was brought in from outside the company. This was the impetus for both Electronic Arrays and Intersil, with Intersil receiving financial support from two downstream firms. Similarly, VLSI was formed with venture capital support by the head of Synertek after Synertek was acquired by a non-semiconductor firm. In all three of these cases, the parent

firm exited the industry soon after the formation of its spinoff.

TABLE 3: Leading Silicon Valley Semiconductor Spinoffs, 1957-1986

FIRM (PARENT)	YEAR	IMPETUS	POSITION	FINANCE
Fairchild (Shockley)	1957	Strategic disagreement (silicon R&D/transistors), Management conflict		Fairchild Camera & Instrument
Amelco (Fairchild)	1961	Strategic disagreement (ICs)	Founder	Teledyne
Signetics (Fairchild)	1961	Strategic disagreement (ICs)	IC R&D pioneers	Investment banks
Electronic Arrays (GME)	1967	Management conflict after acquisition by non-semiconductor firm	Senior engineer	Not available
Intersil (Union Carbide)	1967	Stock options, management conflict with non-semiconductor parent	Founder	SSIH and Olivetti
National (Fairchild)	1967	Stock options, management conflict with non-semiconductor parent	Head of production	National Semiconductor
Intel (Fairchild)	1968	Management conflict, technical frustration (MOS)	Founder	Venture Capital
AMD (Fairchild)	1969	Management conflict after CEO hired from outside firm	Head of marketing	Minimal capital
Zilog (Intel)	1974	Personal tensions	Top R&D engineer	Exxon
VLSI (Synertek)	1979	Management conflict after acquisition by non-semiconductor firm	Founder	Venture capital
LSI Logic (Fairchild)	1980	Management conflict after acquisition by non-semiconductor firm	CEO	Venture capital
Linear (National)	1981	Strategic Disagreement (linear circuits)	Head of linear division	Venture capital
Cypress (AMD)	1982	Strategic Disagreement (CMOS)	Division manager	Venture capital

C. Lasers

Spinoffs have also been prominent in lasers, which come in many different forms. Table 4 summarizes information for spinoffs in each of the eight main types of lasers based on Klepper and Sleeper [2005] and supplementary information collected by Sherer [2006].

Similar to autos and semiconductors, internal disagreements were prominent in the formation of these spinoffs, and in laser spinoffs generally (Sherer [2006]). The first spinoff, Uniphase, is illustrative. Its parent, Spectra Physics, studied various ways to improve its Helium Neon (HeNe) laser, which was used in scanners. It chose not to pursue one of the options it explored, which was to miniaturize the laser. An R&D manager that worked on the project felt that miniaturization had more promise than Spectra Physics did and left along with an engineer and a marketing manager from another firm to form Uniphase to pursue their ideas. Their efforts led to the development of hand-held scanners, which launched Uniphase’s success.

TABLE 4: Representative Laser Spinoffs

Firm (Parent)	Year	Laser	Impetus	Position
Uniphase (Spectra-Physics)	1981	HeNe	Strategic disagreement	Technical employees
Laakman (Hughes)	1980	CO2	Shunned new technology	Technical employees
JEC (Holobean)	1980	Solid State	Parent acquired & moved	Technical employees, GM
Cynosure (Candela)	1992	Dye	Strategic disagreement	Founders
Lexel (Coherent)	1974	Ion	Technical disagreement	Technical employees
Laser Diode (RCA)	1968	Semiconductor	Parent failure	Technical employees
Questek (Lambda-Physik)	1984	Excimer	Parent acquired & compensation	U.S. president
Omnichrome (Xerox)	1982	HeCd	Internal dispute	Technical employees

The stories behind a number of the other spinoffs in Table 4 are similar. Husband and wife technical workers at Hughes licensed technology they had patented there to develop a variant of Hughes' Carbon Dioxide (CO₂) laser that Hughes, which was primarily a defense contractor, was not interested in developing. The CEO and co-founder of Candela, a producer of Dye lasers, along with an engineer and the director of regulatory affairs at Candela, purchased its research division and founded Cynosure to develop a smaller, cheaper Dye laser they were working on after Candela declined to commercialize it. Coherent explored the use of a ceramic tube to improve its Ion laser, but abandoned it due to manufacturing problems. An engineer that suggested a solution to the problem that was not heeded left with two other employees to form Lexel to pursue their ideas. After RCA encountered difficulties developing a semiconductor laser for defense applications, an engineer involved in the effort left with three other managers/technical workers to found Laser Diode Labs to develop a comparable laser. Last, after an internal dispute, Xerox abandoned Helium Cadmium (HeCd) lasers, but technical employees left to form Omnicrome to continue producing the HeCd lasers.

The other two spinoffs in Table 4, JEC and Questek, were both formed after their parent firm was acquired. In the case of JEC its parent moved and ceased servicing some of its old buyers, opening an opportunity for two technical employees and a general manager to start a firm to service these customers. In the case of Questek, tensions over compensation from the sale of the parent led its U.S. president to found a competing firm.

D. General Themes

Three themes of note emerge from the case studies:

1. Many of the spinoffs were based on technical ideas that originated within their parent firm but the parent declined to support aggressively or at all. For example, this includes the two ideas for smaller cars proposed by Coffin and Chapin at Olds Motor Works and E. R. Thomas-Detroit, the development of integrated circuits at Fairchild, and the miniaturization of helium neon and dye lasers at Spectra Physics and Candela respectively. In some instances, disagreements over the ideas blossomed into full-fledged fights over the control of the parent firm. Invariably internal champions for these ideas ended up leaving in frustration after failing to convince the powers that be of the merit of their ideas. This is a common theme among spinoffs (Garvin [1983]). While surely influenced by financial factors, the primary motive for the champions leaving to found their own firms appears to have been the desire to pursue ideas they believed in (cf. Braun and MacDonald [1978, pp. 138-139]).

2. A number of the spinoffs were based on disagreements over the strategic direction of the parent firm and/or fundamental management practices related to the organization of the parent and its method of rewarding high-level employees. Many of these disagreements were prompted by a change in control of the firm associated with a change in ownership or a new CEO being brought in from outside the firm. Similar tensions seem to have existed in firms that were financed and controlled from the outset by firms in another industry. While leading firms tended to spawn the most spinoffs, some, most notably Olds and Fairchild, were in decline when the bulk of their spinoffs occurred.

3. Founders of the spinoffs were often top managers, including founders and CEOs, and/or top scientists and engineers. It was rare for founders in automobiles and semiconductors to be able to finance their own firms. They often received funding from upstream and downstream firms, executives and firms in the industry itself, relatives, and in the semiconductor industry venture capitalists, many of whom were themselves veterans of the industry.

IV. A Model of Disagreements and Spinoffs

The case study evidence has highlighted the conflicts that arise when members of a management team fail to agree on the strategic direction their firm should take, and how sufficient disagreement may induce some individuals to abandon the firm to pursue their own ideas. In this section we develop a model of disagreements and explore whether such a model can explain the empirical regularities concerning spinoffs that were summarized in Table 1.

The model builds on the Bayesian dial-setting model of Jovanovic and Nyarko [1995]. The firm's problem is to choose a strategy, x , as close as possible to a target, θ . Given θ , strategy x yields a value of the firm given by $v = A - (\theta - x)^2$. The strategy is chosen by a team of n managers, who do not know θ and must learn it over time from observation of noisy signals. Each manager joins the firm at time zero with prior belief that θ is a draw from a Normal distribution. All managers have the same prior mean of zero, but their prior variances may differ. In each subsequent period, managers observe distinct signals drawn from Normal distributions with common mean θ and potentially distinct variances. By Bayes' rule, beliefs at the end of period t are also Normal, and we denote the subjective means and variances by θ_{it} and σ_{it} , $i = 1, 2, \dots, n$. There is no gain to experimentation when both prior and signals are normally distributed, so manager i believes the optimal strategy is $x = \theta_{it}$, yielding an expected value of $A - \sigma_{it}$. Of course, the firm can only implement one strategy. We assume the firm implements a weighted average of the choices of each individual, $x_t = \sum_{i=1}^n \omega_i \theta_{it}$, where $\sum_{i=1}^n \omega_i = 1$ and ω_i reflects the influence of individual i in the firm's decision making process.

From individual i 's perspective, the strategy chosen by the firm may not be optimal. His expectation of the firm's value is

$$\begin{aligned} E_{it}[v] &= A - E_{it}\left[(\theta - x_t)^2\right] \\ &= A - \Delta_{it}^2 - \sigma_{it}, \end{aligned} \tag{1}$$

where $\Delta_{it} = \theta_{it} - x_t$ measures i 's disagreement with the firm's strategy. Relative to i 's optimal strategy, the shortfall in the expected value of the firm is Δ_{it}^2 . Let k denote the cost of organizing a firm. We assume that individual i chooses to start his own firm as soon as $\Delta_{it}^2 \geq k$.

In modeling disagreement among members of a management team, we must immediately contend with an intellectual challenge. In each period, it is assumed that each decision maker conveys the mean of his subjective distribution to the other decision makers in the firm in order to communicate the strategy he thinks the firm should follow. This is tantamount to conveying the decision maker's prior mean and the mean of his past signals on θ , which each decision maker can use to update his subjective distribution on θ . Geanakoplos and Polemarkcharkis [1982] have shown that under general conditions this will cause the views of all decision makers to converge, so that they all have the same subjective distribution for θ and no disagreement can occur. Two mechanisms can be used to prevent this convergence and preserve the possibility of disagreements. First, one may assume that managers have prior beliefs that are held privately and that differ from the priors of their colleagues (*cf.* van den Steen [2001, 2004]). Second, one may assume that managers are not precisely informed about the accuracy of their colleagues' signals. Amador and Landier [2003] and Klepper and Thompson [2007] have taken this second approach in studies of spinoffs that assume all individuals are overconfident, causing them to put more weight on their own signals than on those of other decision makers in the firm. We induce disagreements using a blend of both approaches.

Suppose that in some firms certain decision makers are more likely to have superior ideas, but other decision makers in the firm are unable to recognize this. Indeed, in many of the case studies the limited backgrounds of key decision makers seem to have hindered their ability to evaluate new ideas that arose within the firm. We model this as follows. Suppose that the n^{th} decision maker in these firms joins the management team better informed about the target than his colleagues, and that he subsequently also receives more precise signals. For compactness, we characterize this with a single parameter, $\alpha \in (0, 1)$. Assume that the true distribution of θ is $N(0, (1 - \alpha)\sigma_\theta)$; that individual n knows this, while his colleagues

know only that it is a draw from $N(0, \sigma_\theta)$; and that individual n receives signals distributed as $N(\theta, (1-\alpha)\sigma)$, whereas all other decision makers in the firm receive signals distributed as $N(\theta, \sigma)$. Individual n knows the variance of his prior and signals, but the other decision makers in the firm believe that every decision maker has the same prior variance of σ_θ and the same signal variance of σ . The parameter α varies across firms. When $\alpha > 0$, we shall use the shorthand terms α -type individual and α -type firm to index the superior ability of individual n and to identify the type of firm he works for. Firms without an α -type individual, whose managers are trying to learn the value of a draw from $N(0, (1-\alpha)\sigma_\theta)$, will be termed $\beta(\alpha)$ -type firms.

Disagreements cannot arise in $\beta(\alpha)$ -type firms, so we focus here on the dynamics governing α -types. Let $\bar{s}_{it} = t^{-1} \sum s_{it}$ denote the mean signals of individual i , which we assume are conveyed to all decision makers in the firm. Individuals $i = 1, 2, \dots, n-1$ weigh everyone's information equally based on their beliefs about the precision of the information, which yields a posterior mean of

$$\theta_{it} = \frac{t\sigma_\theta \sum_{i=1}^n \bar{s}_{it}}{n(t\sigma_\theta + \sigma)}, \quad i = 1, 2, \dots, n-1. \quad (2)$$

In contrast, an α -type individual weighs his own information more than anyone else's, yielding a posterior mean of

$$\theta_{nt} = \frac{\lambda t\sigma_\theta \left(\bar{s}_{nt} + (1-\alpha) \sum_{i=1}^{n-1} \bar{s}_{it} \right)}{n(t\sigma_\theta + \sigma)}. \quad (3)$$

where $\lambda = n / [(n-1)(1-\alpha) + 1] > 1$.¹¹ The difference between the α -type individual's optimal strategy and the strategy chosen by the firm is then given by

$$\Delta_{nt} = \frac{(1-\omega_n)t\sigma_\theta}{n(t\sigma_\theta + \sigma)} \left((\lambda-1)\bar{s}_{nt} + (\lambda(1-\alpha)-1) \sum_{i=1}^{n-1} \bar{s}_{it} \right). \quad (4)$$

¹¹ In calculating equations (2) and (3), we have also assumed that each individual treats the priors of his colleagues as signals. This does nothing to change the zero subjective mean, but it alters the subjective variances prior to observing the private signals. For individuals $i \neq n$ the variance prior to observing the private signals is σ_θ/n ; for individual n it is $\lambda(1-\alpha)\sigma_\theta/n$. The assumption is of no great consequence, but it serves to simplify what follows by placing several expressions on common denominators.

Individuals $i = 1, 2, \dots, n-1$ have the same views about what the firm should do. If individual n is not an α -type, he shares this common view. But each α -type individual places more weight on his own information than anyone else's and so differs from their view about what the firm should do. He only has a limited influence on the firm, so the firm chooses a strategy different from his optimal choice.

Disagreements are driven by *differences* in opinions about θ , but they do not depend at all on its value. Nonetheless, the realized value of θ does affect the value of the firm. To see this, note that the expected value of the firm conditional on θ is

$$E[v_t | \theta] = A - \int_{-\infty}^{\infty} (\theta - x_t)^2 dF(x_t | \theta), \quad (5)$$

where

$$\begin{aligned} x_t &= (1 - \omega_n)\theta_{it} + \omega_n \theta_{nt} \\ &= \frac{t\sigma_\theta}{n(t\sigma_\theta + \sigma)} \left[\left((1 - \omega_n) + \lambda\omega_n(1 - \alpha) \right) \sum_{i=1}^{n-1} \bar{s}_{it} + \left((1 - \omega_n) + \lambda\omega_n \right) \bar{s}_{nt} \right]. \end{aligned} \quad (6)$$

The random variable \bar{s}_{nt} is normally distributed with mean θ and variance $\alpha\sigma/t$. The variable $\sum_{i=1}^{n-1} \bar{s}_{it}$ is also normal, with mean $(n-1)\theta$ and variance $(n-1)\sigma/t$. Hence $F(x_t | \theta)$ is the distribution of a normal random variable with mean $\mu_t = \theta / (1 + \sigma / t\sigma_\theta)$, and variance

$$\text{var}(x_t) = \frac{t\sigma_\theta^2\sigma}{n^2(t\sigma_\theta + \sigma)^2} \left[(n-1) \left((1 - \omega_n) + \lambda\omega_n(1 - \alpha) \right)^2 + (1 - \alpha) \left((1 - \omega_n) + \lambda\omega_n \right)^2 \right], \quad (7)$$

which is independent of θ . Rewrite (5) as

$$\begin{aligned} E[v_t | \theta] &= A - \int_{-\infty}^{\infty} \left((\theta - \mu_t) - (x_t - \mu_t) \right)^2 dF(x_t | \theta) \\ &= A - (\theta - \mu_t)^2 + 2(\theta - \mu_t) \int_{-\infty}^{\infty} (x_t - \mu_t) dF(x_t | \theta) - \int_{-\infty}^{\infty} (x_t - \mu_t)^2 dF(x_t | \theta) \\ &= A - \theta^2 \left(\frac{\sigma}{t\sigma_\theta + \sigma} \right)^2 - \text{var}(x_t), \end{aligned} \quad (8)$$

which is strictly increasing in α and ω_n . Even though the superior ability of the α -type agent is not recognized by his colleagues, the firm benefits from the greater precision of his signals. As $\text{var}(x_t)$ is independent of θ , $E[v_t | \theta]$ is strictly decreasing in θ^2 . That is, the closer θ is to zero, and the closer the mean of the signals is to θ , the greater will be the value of the firm.¹²

We shall explore the ability of this framework to explain the empirical regularities in the following subsections. Before doing so, however, six issues related to stylizations in the model designed to keep the analysis simple merit some brief discussion.

- *The value of the firm.* In Jovanovic and Nyarko [1995], the choice of x in each period yields an immediate one-period observed payoff. The payoff, which may be profit, output, productivity, or some other measure of performance, is stochastic. The decision-maker's task is to try and infer the value of θ from these noisy payoffs. The current belief about θ determines the decision maker's subjective expectation of the next period's payoff as well his subjective expectation about the value of the firm. We have chosen to directly model beliefs about the expected value of the firm. This is in part for compactness. But more substantively, many disagreements involve learning about strategies that have yet to yield directly observable payoffs. Consequently, they often also involve signals that are not a function of one-period payoffs. In one sense our model is more general than the formulation in Jovanovic and Nyarko [1995], because our noisy signals may include, in addition to any one-period payoffs that are observed, less tangible types of information.

- *Invariance of the target.* While our model assumes that each firm must learn the value of an invariant target, this does not necessarily imply that the environment in an industry never changes. We do not need to assume that all firms face the same target. The model is consistent with, for example, later entrants facing different draws, and perhaps a different distribution of draws, of the target than earlier entrants due to the evolution of an industry's technological frontier. We can also analyze the consequences of a single, unanticipated change in the target, which we consider in subsection IV.B. In addition, it is possible to extend our model to include continuously evolving stochastic targets, such as might result from continuous change in the economic environment. Tools such as the Kalman filter are avail-

¹² Of course, decision makers do not know how close their prior mean or their signals are to θ when they make their strategic choices—we assume they receive no objective information about the quality of their choices. It is only ex-post that the value of the firm is revealed to decision makers.

able to model learning about the distribution of stochastic processes. We do not explore this extension in the current paper. Although doing so might provide some additional insights, it is a complication that is unnecessary for our primary goal of exploring the model’s consistency with the empirical regularities.

- *The stopping criterion.* We have assumed that individual i forms a spinoff the first period that $\Delta_{it}^2 \geq k$. However, when $\Delta_{it}^2 = k$ the value of continuing with the parent firm is strictly greater than the value of forming a spinoff, because remaining with the firm allows the agent to observe the size of the next period’s disagreement. Modeling sophisticated agents aware of this option value requires a dynamic programming approach to the optimal stopping problem. In practice, such analyses have proved intractable, because the stopping region fluctuates over time in complex ways. As a result researchers have frequently resorted to approximating the dynamic stopping problem by replacing the time-varying stopping region with its asymptotic counterpart.¹³ It turns out that the approximation is exactly equivalent to ignoring the continuation value, so our assumption that a spinoff is formed as soon as $\Delta_{it}^2 \geq k$ implements the standard approximation.

- *Decision making authority.* The weights used in determining the action of the firm are exogenous. One might suppose that the weights are determined by the outcome of some bargaining process, or that the firm is designed to create weights that lead to efficient actions. In the latter case, the optimal weights depend upon the accuracy of managers’ beliefs about the accuracy of their own and their colleagues’ signals. As we shall shortly see, if all managers are precisely informed about the accuracy of everyone’s signals, an arbitrary set of weights is both efficient and acceptable to team members engaged in bargaining, because in this case disagreements never arise. When managers are not precisely informed about the accuracy of everyone’s signals, disagreements may arise, and some weighting schemes will dominate others. However, there is no obvious way for the firm to select the ideal weighting scheme when it depends upon mistakes about signal precision, of which managers are unaware.

- *No strategic transmission of information.* We assume the firm’s action is a weighted average of each manager’s reported belief. When disagreements exist about the optimal action, there may be incentives for each manager to mislead his colleagues by engaging in cheap talk about his beliefs. Our focus, however, is on whether the limited ability of decision makers to

¹³ Jovanovic’s [1979] classic model of labor turnover takes this approach; Thompson [2008] has done so recently in a model of marital discord.

assess novel ideas can account for the various empirical regularities. Accordingly, we assume throughout that agents accurately represent their beliefs and do not engage in cheap talk.¹⁴

- *No competitive implications of spinoffs.* Spinoffs are potential competitors to their parents. Thus, parents frequently discourage them by means of contractual sticks such as non-compete covenants, legal sticks such as filing suits for intellectual property infringement, and monetary carrots such as schemes to reward employees for revealing their ideas. Incumbent concerns about potential competition from spinoffs has been the subject of some theorizing (see, e.g., Amador and Landier [2003], Hellman [2007]), but there remain many open questions. However, we put these issues aside in this paper in order to focus on the *mechanics* of spinoffs spawned by disagreement. The task we have set for ourselves turns out to be complex enough, and it is only after understanding these mechanics that we can begin to explore how parent firms might respond to competitive threats from potential spinoffs.

A. Firm age and the probability of a spinoff

The first regularity in Table 1 is that the hazard of spinoff formation first rises, then falls, with increasing age of (parent) firms. The model predicts this for α -type firms. A spinoff occurs as soon as $\Delta_{nt}^2 > k$. We are consequently interested in the distribution of the Markov time, T , that satisfies the first-passage problem

$$T = \min_{\tau} \left\{ \tau : \Delta_{n\tau}^2 \geq k \right\}. \quad (9)$$

To solve (9), we transform it into a first-passage problem involving a standard random walk and then follow conventional procedure by analyzing its continuous-time analog (cf. Cox and Miller [1965]). Define

$$\begin{aligned} \phi_t &= \Delta_{nt} \sqrt{\frac{t}{\text{var}(\Delta_{nt})}} \\ &= \frac{(t\sigma_{\theta} + \sigma)n\sqrt{1 + (1 - \alpha)(n - 1)}}{\alpha\sigma_{\theta}\sqrt{\sigma(n - 1)(1 - \omega_n)}} \Delta_{nt}. \end{aligned} \quad (10)$$

¹⁴ The cheap talk problem has been studied in a variety of settings by, *inter alia*, Crawford and Sobel [1982] and Alonso, Dessein and Matouscheck [2006]. They find in a range of settings that, instead of reporting their beliefs, agents report only an interval in which their beliefs lie.

The random variable ϕ_t is normal with zero mean and variance t , with increments that are independent standard Normals. The continuous-time stochastic process, $\phi(t)$, that gives rise to the same distribution as ϕ_t at $t = 0, 1, 2, \dots$, is a standard zero-drift Wiener process with boundary condition $\phi(0)=0$. We next transform the boundary for the first-passage problem, so that the distribution of T is unaffected by the transformation of the stochastic process. This is achieved upon replacing Δ_t with $\pm\sqrt{k}$ in (10), to obtain two absorbing barriers for $\phi(t)$ given by

$$\phi^*(t) = \pm(\phi_1^* + \phi_2^*t), \quad (11)$$

where

$$\phi_1^* = \frac{n\sqrt{\sigma(1+(1-\alpha)(n-1))k}}{\alpha\sigma_\theta\sqrt{(n-1)(1-\omega_n)}} \quad (12)$$

and

$$\phi_2^* = \frac{n\sqrt{(1+(1-\alpha)(n-1))k}}{\alpha\sqrt{\sigma(n-1)(1-\omega_n)}}. \quad (13)$$

The transformed problem is therefore one of finding the distribution, $F(T | \phi_1^*, \phi_2^*)$, of the Markov time T that satisfies

$$T = \min_t \{t : |\phi(t)| \geq \phi_1^* + \phi_2^*t\}. \quad (14)$$

Equation (14) describes a first passage problem for a Wiener process to either of two barriers, both of which are moving away from the mean of the process at a linear rate (see Figure 1). A convenient consequence of this transformation is that all parameter changes affect the problem only by moving the barriers. Note, for example, that if $\alpha = 0$ or $\omega_n = 1$ the absorbing barriers are infinitely far from the origin and hence unattainable by any sample path. Thus, $\beta(\alpha)$ -type firms, and α -type firms in which individual n makes all the decisions, never produce spinoffs.

The distribution $F(T | \phi_1^*, \phi_2^*)$ can be written explicitly and is given as Theorem A.2 in Appendix A. It is easy to verify that the density, $F'(T | \bullet)$, is unimodal and has boundary condition $F'(0) = 0$. It then follows that the hazard of spinoff formation,

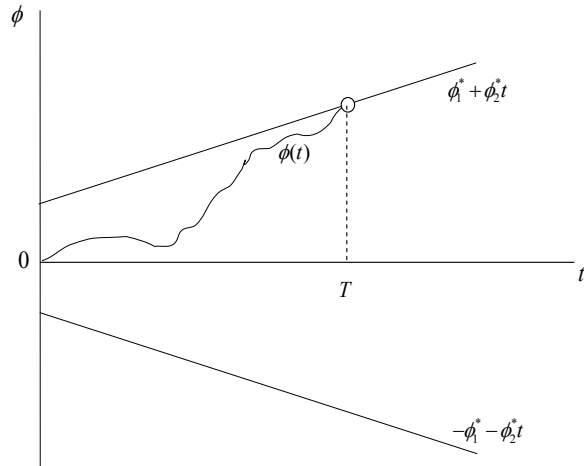


Figure 1. The first passage problem. The sample path has been drawn artificially smooth for visual clarity.

$h(t) = F'(t) / (1 - F(t))$, begins at zero and rise monotonically, at least until the mode of the density is reached. We also show, in Appendix A, that $\lim_{T \rightarrow \infty} F(T | \phi_1^*, \phi_2^*) < 1$, so eventually the hazard must decline to zero. However, we must resort to numerical examples to show the hazard declines monotonically after reaching its peak. Figure 2 illustrates a typical numerical plot, showing a sharp rise to a unique maximum, followed by a more gradual and asymptotic decline towards zero. Thus, consistent with the first empirical regularity in Table 1, the model predicts the rate of spinoff formation first rises and then falls with firm age.

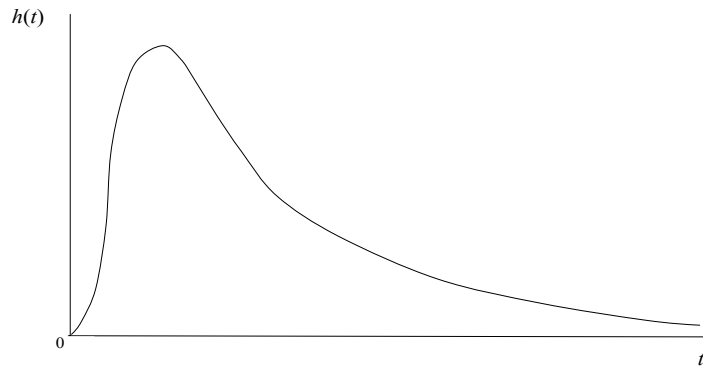


Figure 2. The hazard of spinoff formation

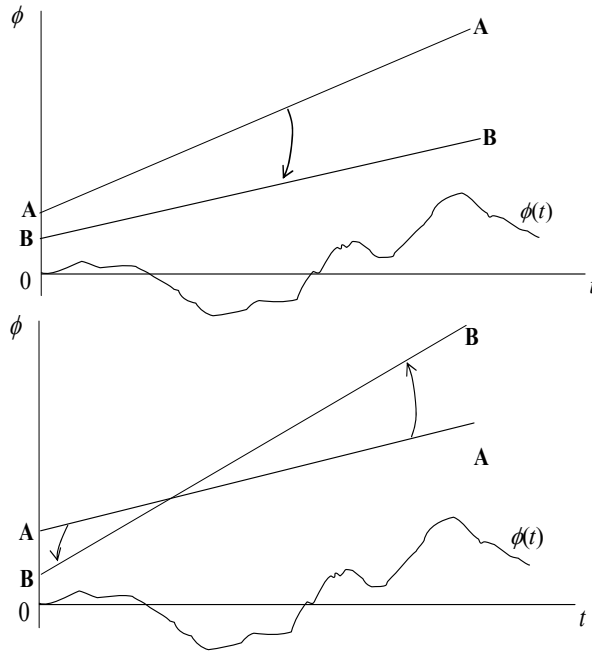


FIGURE 3. Upper panel: Increases in α , and decreases in ω_n and k , cause the absorbing barriers to move from **AA** to **BB**. Lower panel: A reduction in σ causes the absorbing barriers to move from **AA** to **BB**. Only the upper barriers are shown.

Using numerical analysis, it can also be verified that the hazard of spinoff formation $h(t)$ is increasing in α and σ_θ , and decreasing in ω_n and k for all $t > 0$. These comparative dynamics are illustrated in the upper panel of Figure 3. Both $|\phi_1^*|$ and $|\phi_2^*|$ decline as a result of an increase in α , or a reduction in ω_n or k . As a result, the barriers move toward the origin at $t = 0$ and become flatter, as indicated by a shift from **AA** to **BB**. An increase in σ_θ reduces $|\phi_1^*|$ but does not affect $|\phi_2^*|$; this shifts the barriers inwards without altering their slopes, and also unambiguously increases the hazard of spinoff formation. None of these effects are counter-intuitive. For example, disagreements are predicated on the existence of α -type individuals with limited control over the firm's choice of strategy. As a consequence, it is unsurprising that increases in α and reductions in ω_n , both of which raise the variance of disagreements at every point in time, increase the hazard of spinoff formation at every point in time.

The effects of changes in the variance of signal noise is perhaps less obvious. A reduction in σ reduces $|\phi_1^*|$ and increases $|\phi_2^*|$. This shifts the barriers as shown in the lower panel of Fig-

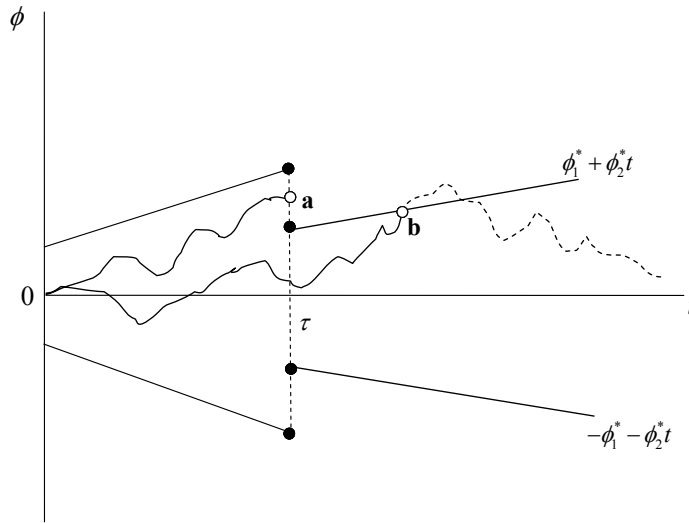


FIGURE 4. The effect on the absorbing barriers of decreased influence of the n^{th} individual

ure 3, and it makes early hits to the barriers more likely and later hits less likely. A reduction in σ has two effects. First, it increases the rate of learning about θ , and this reduces the propensity to disagree. Second, it increases the responsiveness of managers to any given sequence of signals, and this encourages disagreement. The latter [former] effect dominates for small [large].

B. Acquisitions, CEO changes, and the probability of a spinoff

The second regularity in Table 1 is that spinoffs are more likely around the time of an acquisition or change in the CEO, especially when the acquisition is by a firm in another industry or the new CEO comes from outside the firm. Acquisitions and changes in the CEO may induce changes in the spinoff hazard through two channels. First, they commonly result in reorganizations that reduce the decision-making authority of incumbent managers. This might be especially true when the acquiring firm comes from another industry or the CEO comes from another firm and has different ideas about how to run the firm. Second, they may lead to a change in the target, θ , that induces new uncertainty about the right strategy. Figure 4 illustrates the effect of an acquisition or change in the CEO that reduces the decision-making weight of individual n . An acquisition or change in the CEO at time τ shifts the absorbing

barriers in and reduces the absolute value of their slopes.¹⁵ Some sample paths for $\phi(t)$ are also illustrated. An individual n that found himself at point \mathbf{a} at time τ opts to depart the parent company immediately and form a spinoff. Individuals that do not depart at τ nonetheless face increased risk of doing so after τ . For example, an individual arriving at \mathbf{b} will form a spinoff even though he would not have done so had the parent company not been acquired or a new CEO hired. The hazard increases immediately following an acquisition or change in the CEO. Thereafter it may follow either of two possible paths, declining monotonically over time or rising initially before falling.

C. Firm quality and the probability of a spinoff

The third regularity in Table 1 is that better performing firms are more likely to spawn a spinoff, where performance is measured over a firm's lifetime. The *ex ante* probability of a firm spawning a spinoff, $\lim_{T \rightarrow \infty} F(T | \phi_1^*, \phi_2^*)$, is given in Appendix A. It is strictly decreasing in the product of ϕ_1^* and ϕ_2^* ,

$$\phi_1^* \phi_2^* = \frac{n^2 (1 + (1 - \alpha)(n - 1))k}{\alpha \sigma_\theta (n - 1)(1 - \omega_n)}. \quad (15)$$

Hence, the probability of a firm ever spawning a spinoff is increasing in θ and independent of the realized value of θ .¹⁶ We have already shown that the expected quality of (parent) firms is increasing in α and ω_n , and decreasing in θ^2 . Therefore, variations in α across firms will give rise to a positive correlation between the expected quality of firms and the rate at which they spawn spinoffs, consistent with the third regularity. Intuitively, spinoffs can only arise in α -type firms. On average these firms are better performers, and the greater is α then the greater is the probability of a spinoff over the firm's lifetime and the greater the expected performance of the firm over its lifetime.

The case studies indicated that in notable instances, exemplified by Olds Motor Works and Fairchild Semiconductor, high quality firms spawned the bulk of their spinoffs when they

¹⁵ An increase in the degree of uncertainty about the target has a similar effect: in this case the absorbing barriers shift in without altering the slope.

¹⁶ This is as expected, as we have already shown by numerical means that the hazard responds to these parameters in the same direction. Interestingly, although the variance, σ , of the signals alters the spinoff hazard at every point in time, it has no bearing on the probability that a spinoff is ever formed. That is, spinoffs are no more likely in noisy environments than in environments with informative signals, but if they happen they are likely to happen earlier.

were in decline. This raises the possibility that *at the time of their spinoffs*, firms that spawned spinoffs were not necessarily better performers than other firms without spinoffs, although they had been superior at earlier stages of their lives. Our model is consistent with these observations, for two reasons. First, the contemporaneous performance of α -type parents that spawned spinoffs at age τ is on average less than that of α -type and $\beta(\alpha)$ -type non-parents of the same age. The reason is that emerging disagreements that ultimately led to the spinoff also induce a deterioration in the relative performance of parents. Second, the effect of variations in α on the timing of spinoffs causes the average value of α to be greater among parents than among non-parents for young firms, but less for older firms. As a result, the model implies that (i) firms that are initially superior are more likely to spawn spinoffs in the future, (ii) their relative performance declines as they approach the age at which they spawn spinoffs and, (iii) firms that spawn spinoffs at ripe ages are worse performers than non-parents.

We establish these implications of the model by numerical means. Let $E[v_\tau^\beta | \alpha]$ denote the average quality at age τ of $\beta(\alpha)$ -type firms, $E[v_\tau^N | \alpha]$ the average quality of α -type firms that have not spawned a spinoff by age τ , and $E[v_\tau^S | \alpha]$ the average quality of α -type firms that spawn a spinoff at exactly age τ . Intuition suggests that $E[v_\tau^N | \alpha] > E[v_\tau^S | \alpha]$ because a spinoff requires that at least some members of the firm's management team have received misleading signals. At the same time, we expect that $E[v_\tau^N | \alpha] > E[v_\tau^\beta | \alpha]$ because the former benefit from the presence of the α -type individual. Appendix B derives explicit expressions for the expected values, numerical analysis of which is consistent with intuition. Figure 5 provides representative plots showing that $E[v_\tau^N | \alpha] > E[v_\tau^S | \alpha]$. Although we were unable to anticipate the sign of $E[v_\tau^\beta | \alpha] - E[v_\tau^S | \alpha]$, Figure 5 shows that it is positive, and that $E[v_\tau^\beta | \alpha]$ is in fact very close in value to $E[v_\tau^N | \alpha]$ at any age.¹⁷ Thus, as claimed, parents of α -type spinoffs are outperformed by α -type and $\beta(\alpha)$ -type non-parents of the same age. Given that the conditional expected value of all α -type firms are the same at birth, regardless of whether they subsequently spawn a spinoff, and given that $E[v_0^N | \alpha] > E[v_0^\beta | \alpha]$, Figure 5 also implies that firms spawning spinoffs must experience a relative decline in performance prior to spawning a spinoff.

When variations in α across firms is sufficiently strong, the poor contemporaneous relative performance of parents may be more than offset at young ages by selection effects. In order for firms to spawn spinoffs when young, the impetus for disagreement must be unusually strong. Consequently, the average value of α among parents of spinoffs, $\bar{\alpha}_{S_\tau}$, is relatively

¹⁷ Several alternative choices of parameters yielded similar plots and lead to the same conclusions.

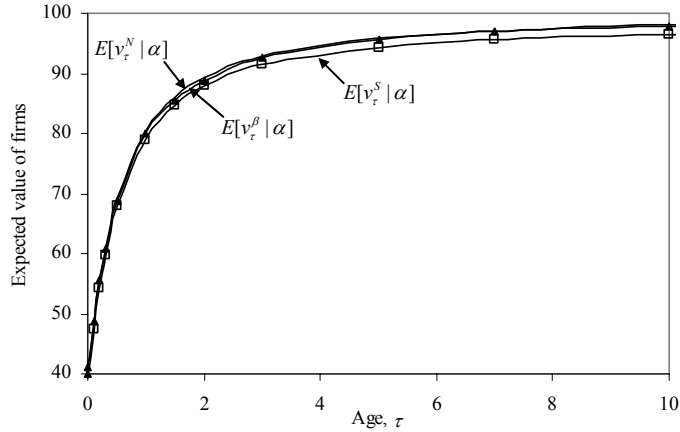


FIGURE 5. Average firm values, by age τ . Numerical evaluations of appendix equations (B.6), (B.9), and (B.12), using parameter values $n=5$, $\sigma_\theta=100$, $\sigma=100$, $k=1$, $\omega_n=0.2$, and $\alpha=0.4$

high when the parents are young. But $\bar{\alpha}_{s_\tau}$ declines monotonically with age because, when enough time has passed, high α -type firms have made more progress in learning the target. Eventually $\bar{\alpha}_{s_\tau}$ falls below both the population average, $\bar{\alpha}$, and the average of non-parent α -type firms, $\bar{\alpha}_{N_\tau}$. Appendix B derives explicit expressions for $\bar{\alpha}_{s_\tau}$ and $\bar{\alpha}_{N_\tau}$; Figure 6 provides a numerical illustration using the same parameter values as in Figure 5 except that α is distributed uniformly over $[0.6, 0.9]$. For small τ , the difference between $\bar{\alpha}_{s_\tau}$ and $\bar{\alpha}$ is positive, and it is large relative to the differences in the conditional expected values of the firms. Thus, although $E[v_\tau^N | \alpha] > E[v_\tau^\beta | \alpha] > E[v_\tau^S | \alpha]$, the differences in unconditional expected firm values, $E[v_\tau^S] - E[v_\tau^\beta]$ and $E[v_\tau^S] - E[v_\tau^N]$, are likely to be positive for spinoffs launched early in their parents' lives. At some time prior to τ_0 , these rank orderings are inevitably reversed. Note from the lower panel of Figure 6, however, that the bulk of spinoffs are spawned when $\bar{\alpha}_{s_\tau} \gg \bar{\alpha}$, so the majority of spinoffs in any sample will be spawned when parents have better performance than non-parents.

D. Parent quality and spinoff quality

The fourth regularity in Table 1 states that better performing parents produce better performing spinoffs, where performance is again measured over a firm's lifetime. In the model, the expected value of parents and spinoffs are both increasing functions of α . Consequently,

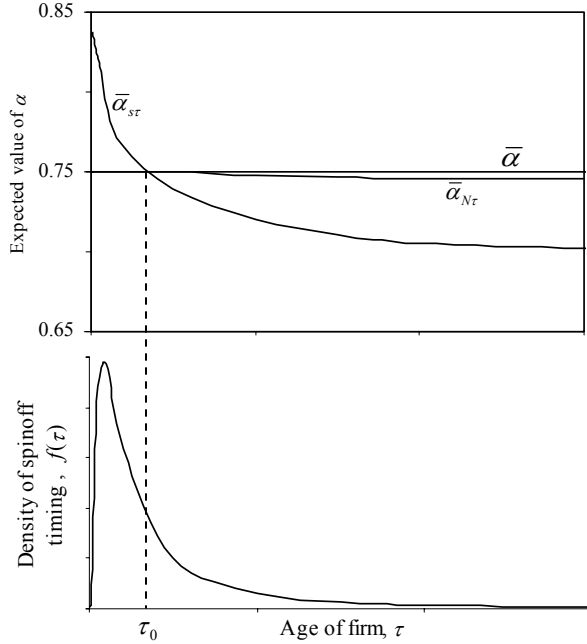


FIGURE 6. Upper panel: Average values of α . $\bar{\alpha}_{N\tau}$ is the expected value at age τ for α -type firms that have not spawned spinoffs by age τ [appendix equation (B.7)]; $\bar{\alpha}_{s\tau}$ is the expected value at age τ for α -type firms that spawn a spinoff at age τ [equation (B.10)]; $\bar{\alpha}$ is the expected value at age τ for β -type firms. Lower panel: Density of spinoff formation by age. Parameter values used are $n=5, \sigma_\theta=100, \sigma=100, k=1, \omega_n=0.2$; the distribution of α is uniform on $[0.6, 0.9]$.

it follows directly that the expected performance of parents and spinoffs will be positively correlated, consistent with the fourth regularity.

We can also analyze the relationship between the expected value of parents *at the time of their spinoffs* and the expected value of their spinoffs among firms spawning spinoffs at any given age τ , which requires conditioning on sample stochastic paths that induce spinoffs. It turns out that the positive correlation between parent and spinoff quality continues to hold, reflecting the influence of α -type individuals on both parent and spinoff performance. We derive the conditional expected value of a spinoff launched when its parent is age τ , $E[\bar{v}_\tau^S | \alpha]$, in the appendix [equation (B.14)], and compare it with $E[v_\tau^S | \alpha]$ [equation (B.9)]. To facilitate comparison, we impose the numerical values, $n=5, \sigma_\theta=100, \sigma=100$, and $k=1$, but leave α, ω_n , and τ as parameters. For these parameter values, the expected values of

parent and spinoff simplify to

$$E\left[v_\tau^S \mid \alpha; \omega_n\right] = \frac{100\alpha + 25\tau(4\tau + 7)}{(1 + \tau)^2} + \frac{25\tau}{(1 + \tau)^2(5 - 4\alpha)} - \frac{1}{(1 - \omega_n)^2}, \quad (16)$$

and

$$E\left[\tilde{v}_\tau^S \mid \alpha; \omega_n\right] = \frac{100\left(\alpha(5 - 7 - 4\tau^2) - 4\alpha^2\right) + \tau(5\tau + 9)}{(1 + \tau)(5 - 4\alpha)}. \quad (17)$$

Both expectations are increasing in α and τ , and hence the expected quality of spinoffs and their parents at the time of their spinoffs are positively correlated. It is also easy to verify that $E\left[\tilde{v}_\tau^S \mid \alpha; \omega_n\right] > E\left[v_\tau^S \mid \alpha; \omega_n\right]$ for all τ , so parents of any age are out-performed by their spinoffs.

E. Spinoff and de novo performance.

The final regularity in Table 1 states that spinoffs are better performers than other *de novo* entrants. The appropriate comparison is of the initial performance of a spinoff formed when a parent is age τ with a firm of age 0. First, conditioning on α , it is easy to verify that $E\left[\tilde{v}_0^S \mid \alpha\right] = E\left[v_0^S \mid \alpha\right] = A - (1 - \alpha)\sigma_\theta$, so that spinoffs formed when their parents are very young (an unlikely event) perform on average no better or worse than a *de novo* firm of the same α -type. We have also just seen that $E\left[\tilde{v}_\tau^S \mid \alpha\right]$ is increasing in τ , so that spinoffs with parents of any age outperform α -type *de novo* firms of the same α -type. As α -type firms of age zero outperform $\beta(\alpha)$ -type firms of the same age, spinoffs also outperform $\beta(\alpha)$ -type firms with the same value of α . However, there is again a potential ambiguity introduced after taking expectations over α , because $\bar{\alpha}_{s\tau} < \bar{\alpha}$ when $\tau > \tau_0$. Thus, for $\tau \leq \tau_0$, spinoffs on average outperform *de novo* firms, although this may not be true for sufficiently large values of τ .

V. Discussion

Intra-industry spinoffs raise numerous questions regarding theory and policy. They are exceptional performers. Is this because they take something from their employer? If so, does this affect the incentives of their employer to engage in activities like R&D? Why don't their employers pursue their ideas?

Answering these and a host of related questions regarding intra-industry spinoffs requires understanding their impetus, the motives of their founders, and the consequences for their parent firms. This task is complicated because there is surely no single motive for their occurrence. We focused on what can be learned about intra-industry spinoffs from accumulating statistical regularities and leading case studies. We showed that a theory of disagreements born from inherent difficulties in evaluating new ideas by decision makers can provide a parsimonious explanation for both the regularities and case studies. While this does not preclude other motivations from being pertinent, hopefully it inspires confidence in the role of our theory in explaining intra-industry spinoffs.

Our model emphasizes that firms are not unitary actors, which can lead to disagreements about the best course of action for a firm. If dissidents have superior ideas, then spinoffs will generally be superior performers, a result which is virtually built into the model. At the same time, before their departure the dissidents will contribute to their parents being superior performers. Consequently, over their lifetime firms that spawn spinoffs will be superior performers. Disagreements are associated with misleading signals, however, so that at the time of their spinoffs parents may be in decline and possibly no longer superior performers, consistent with a number of the case studies. The model implies that the performance of spinoffs and the performance of their parents, both over their lifetimes and at the time of their spinoffs, will be positively correlated. Other theories have attributed this to the superior learning environment for employees at better firms (cf. Franco and Filson [2006]), but our theory demonstrates this is not needed to explain the correlation. Our theory readily explains the repeated finding that organizational changes within firms tend to raise the probability of spinoffs. It can also explain the initial rise and then fall in the probability of spinoffs as firms age, although the eventual decline in the spinoff rate requires a firm's strategic target to remain constant over time, which is surely a limiting feature of the model.

Our theory was not designed to address normative issues regarding spinoffs, but it does offer a novel perspective on such issues. We assumed that firms can have difficulty evaluating novel ideas, although the novelty of ideas is left implicit in our model. And while we have no mechanisms in the model for learning and imitation, which might be thought of as cornerstones for normative implications in our perspective, it seems inevitable that novel ideas will generate positive spillovers as other firms, including parents, imitate successful spinoffs (Klepper [2007c]). It is consequently not hard to envision how in our perspective spinoffs could play a valuable social role. One of the virtues of capitalism is its decentralization of decision making (Nelson [1981]). Spinoffs can be thought of as a means to compensate for the limitations of incumbent firms regarding decisions about strategy and management. They are

thus a key vehicle for the benefits of capitalism to be realized (cf. Hellman and Perotti [2006]). To the extent that spinoffs can be suppressed by incumbent firms through the enforcement of employee non-competes (Stuart and Sorenson [2003], Marx et al. [2007]) and exploitation of the law on trade secrets (Jackson [1998]), it might be advisable to restrict such practices (cf. Gilson [1999], Hyde [2003]).

One of the virtues of our model is that it focuses attention on a distinctive set of issues and questions. As we showed, once we drop the assumption that firms are unitary actors then it becomes possible to understand the case study evidence we assembled on the leading spinoffs and the accumulating stylized facts about intra-industry spinoffs. It is then not much of a leap to see how spinoffs could play a central role in the performance of an economy. Our model provides a way to understand this and probe it further.

Appendix

A. Distributions for First-Passage Problems

We make use of several results concerning the distributions of first-passage problems. These results are collected here:

THEOREM A.1 $\lim_{T \rightarrow \infty} F(T | \phi_1^*, \phi_2^*) = \sum_{n=1}^{\infty} (-1)^{n+1} e^{-2\phi_1^* \phi_2^* n^2} < 1$.

Proof. The distribution was first derived by Doob (1949). To show it is strictly less than one, let $x_n = (-1)^{j+1} \exp\{-2\phi_1^* \phi_2^* j^2\}$ and $s_k = \sum_{j=1}^k x_j$. We have $\lim_{k \rightarrow \infty} |s_k| < \sum_{j=1}^{\infty} \exp\{-2\phi_1^* \phi_2^* j^2\} < \sum_{j=1}^{\infty} \exp\{-2\phi_1^* \phi_2^* j\} = 2(\exp\{-2\phi_1^* \phi_2^*\} - 1)^{-1} < \infty$, and the series is absolutely convergent. Note also that $x_1 > 0$, and $|x_{k+1}| < |x_k| \forall k$. Hence, using a standard property of absolutely convergent alternating series, $\lim_{T \rightarrow \infty} F(T | \phi_1^*, \phi_2^*) \leq x_1 = \exp\{-2\phi_1^* \phi_2^*\} < 1$.

THEOREM A.2 (Choi and Nam [2003, Theorem 7]). *The distribution of first passage times for any $\phi_1^* > 0$, $\phi_2^* > 0$, and $T > 0$ is*

$$F(T | \phi_1^*, \phi_2^*) = 1 - \int_{-x_1}^{x_1} d\Psi(s) + \sum_{j=1}^{\infty} \left\{ e^{-2\phi_1^* \phi_2^* (2j-1)^2} \left(\int_{-x_{2j}}^{x_{2j}} d\Psi(s) + \int_{-x_{3j}}^{x_{3j}} d\Psi(s) \right) - e^{-8\phi_1^* \phi_2^* j^2} \left(\int_{-x_{4j}}^{x_{4j}} d\Psi(s) + \int_{-x_{5j}}^{x_{5j}} d\Psi(s) \right) \right\},$$

where $\Psi(s)$ is the standard normal distribution, $\sqrt{T}x_1 = \phi_1^* + \phi_2^*T$, $\sqrt{T}x_{2j} = (3-4j)\phi_1^* + \phi_2^*T$, $\sqrt{T}x_{3j} = (4j-1)\phi_1^* + \phi_2^*T$, $\sqrt{T}x_{4j} = (1-4j)\phi_1^* + \phi_2^*T$, and $\sqrt{T}x_{5j} = (1+4j)\phi_1^* + \phi_2^*T$.

THEOREM A.3 (Abundo [2002, Theorem 3.3]). *The crossing probability for a two-sided Brownian bridge with initial value 0, terminal value η at time T , and boundaries $\pm(\beta_0 + \beta_1 t)$ is*

$$P(T; \eta, \beta_0, \beta_1) = \begin{cases} 1 - \sum_{j=-\infty}^{+\infty} (-1)^j e^{-2\beta_0 j((\beta_1 + \beta_0/T)j - \eta/T)}, & \text{if } |\eta| < \beta_0 + \beta_1 T \\ 1, & \text{otherwise} \end{cases}.$$

B. Conditional Expected Firm Values.

B.1 *Derivation of $E[v_\tau^N | \alpha]$ and $E[v_\tau^N]$.* Conditional on θ , the value of a firm of age τ is given by

$$v_\tau = A - (\theta - x_\tau)^2. \quad (\text{B.1})$$

Substituting (6) into (B.1):

$$v_\tau = A - \left(\theta - \frac{\tau\sigma_\theta}{n(\tau\sigma_\theta + \sigma)} \left[((1 - \omega_n) + \lambda\omega_n(1 - \alpha)) \sum_{i=1}^{n-1} \bar{s}_{i\tau} + ((1 - \omega_n) + \lambda\omega_n) \bar{s}_{n\tau} \right] \right)^2 \quad (\text{B.2})$$

We consider first the average value, $E[v_\tau^N | \alpha > 0]$, of α -type firms that have not spawned a spinoff. We begin by fixing ϕ_τ at some arbitrary value, say $\bar{\phi}_0$ within the admissible range, $|\bar{\phi}_0| < \phi_1^* + \phi_2^*\tau$ (see Figure B.1). This implies that $\bar{s}_{n\tau}$ and $\sum_{i=1}^{n-1} \bar{s}_{i\tau}$ are related by

$$\bar{s}_{n\tau} = \frac{\alpha \bar{\phi}_0 \sqrt{\sigma(n-1)}}{(\lambda-1)\tau \sqrt{(1+(n-1)(1-\alpha))(1-\omega_n)}} + \frac{1}{n-1} \sum_{i=1}^{n-1} \bar{s}_{i\tau}. \quad (\text{B.3})$$

Substituting (B.3) into (B.2) and letting $y = \sum_{i=1}^{n-1} \bar{s}_{i\tau}$ yields

$$v_\tau^N(\alpha, \theta, \bar{\phi}_0, y) = A - \left(\theta - \frac{\alpha \tau \sigma_\theta \bar{\phi}_0 \sqrt{\sigma(n-1)}}{\tau n (\lambda-1) (\tau \sigma_\theta + \sigma) \sqrt{((n-1)(1-\alpha) + 1)(1-\omega_n)}} - \frac{\tau \sigma_\theta}{(n-1)(\tau \sigma_\theta + \sigma)} y \right)^2.$$

Taking expectations over all values of y ,

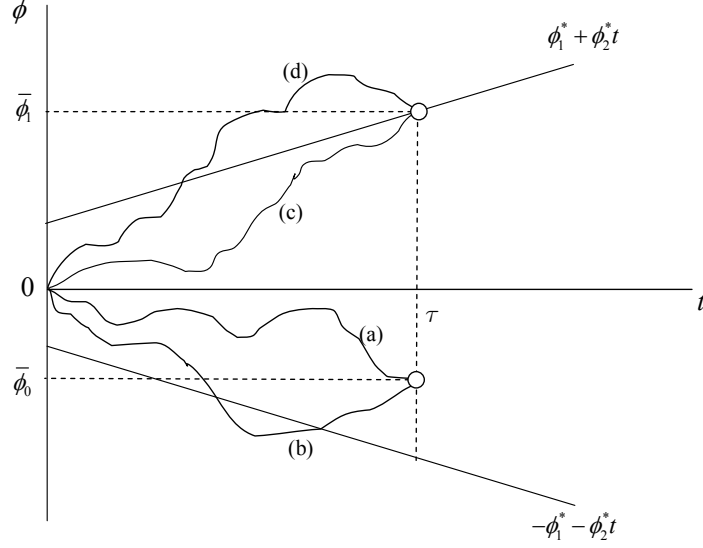


Figure B.1

$$v_\tau^N(\alpha, \theta, \bar{\phi}_0) = A - \int_{-\infty}^{\infty} \left(\theta - \frac{\alpha \tau \sigma_\theta \bar{\phi}_0 \sqrt{\sigma(n-1)}}{\tau n(\lambda-1)(\tau \sigma_\theta + \sigma) \sqrt{((n-1)(1-\alpha)+1)(1-\omega_n)}} - \frac{\tau \sigma_\theta}{(n-1)(\tau \sigma_\theta + \sigma)} y \right)^2 \times f_y(y | \bar{\phi}_0) dy, \quad (\text{B.4})$$

where $f_y(y | \bar{\phi}_0)$ is given by the joint probability that $\sum_{i=1}^{n-1} \bar{s}_{i\tau} = y$ and $\bar{s}_{n\tau}$ satisfies (B.3). That is,

$$f_y(y | \bar{\phi}_0) = \frac{1}{\int_{-\infty}^{\infty} \psi_y(y) \cdot \psi_{\bar{s}_{n\tau}} \left(\frac{\alpha \bar{\phi}_0 \sqrt{\sigma(n-1)}}{(\lambda-1)\tau \sqrt{(1+(n-1)(1-\alpha))(1-\omega_n)}} + \frac{y}{n-1} \right) dy} \psi_y(y) \cdot \psi_{\bar{s}_{n\tau}} \left(\frac{\alpha \bar{\phi}_0 \sqrt{\sigma(n-1)}}{(\lambda-1)\tau \sqrt{(1+(n-1)(1-\alpha))(1-\omega_n)}} + \frac{y}{n-1} \right),$$

where $\psi_y(y)$ is the density of a Normal random variable with mean $(n-1)\theta$ and variance $(n-1)\sigma/\tau$ and $\psi_{\bar{s}_{n\tau}}(\bar{s}_{n\tau})$ is the density of a Normal random variable with mean θ and variance $(1-\alpha)\sigma/\tau$. It is next necessary to exclude sample paths such as (b) in Figure B.1, while including paths such as (a). If the history of the firm did not matter, the distribution of ϕ_τ would be truncated normal with mean zero and truncation points at $\pm(\phi_1^* + \phi_2^* \tau)$. However, values of ϕ_τ close to the truncation points are more likely to have had sample paths that crossed one of the

boundaries at some earlier point in time, and they will consequently appear among the sample of firms that have never spawned spinoffs less frequently than is predicted by $f_y(y | \bar{\theta}_0)$. To account for this, let $\tilde{P}(\bar{\phi}_o, \tau)$ denote the probability that $\bar{\phi}_o$ is reached without $\bar{\phi}_t$ first crossing either boundary. Then an appropriate adjustment to the Normal density for each admissible $\bar{\phi}_0$ is given by

$$\zeta(\bar{\phi}_0, \tau) = \frac{\tilde{P}(\bar{\phi}_o, \tau)}{\frac{1}{\Psi_{\phi_\tau}(\phi_1^* + \phi_2^* \tau) - \Psi_{\phi_\tau}(-\phi_1^* - \phi_2^* \tau)} \int_{-\phi_1^* - \phi_2^* \tau}^{\phi_1^* + \phi_2^* \tau} \tilde{P}(\bar{\phi}_o, \tau) d\Psi_{\phi_\tau}(\bar{\phi}_o)}, \quad (\text{B.5})$$

where $\Psi_{\bar{\theta}_0}(\bar{\phi}_0)$ is the Normal distribution with zero mean and variance τ . The distribution $\tilde{P}(\bar{\phi}_o, \tau)$ is the complement of the crossing probability for a two-sided Brownian bridge with initial value 0, terminal value $\bar{\phi}_0$ at time τ , and boundaries $\pm(\phi_1^* + \phi_2^* t)$. Its formula is obtained directly from Theorem A.3. Using (B.5) to weight (B.4) and then integrating over all admissible values of $\bar{\phi}_0$ yields

$$\begin{aligned} v_\tau^N(\alpha, \theta) &= \frac{1}{\Psi_{\phi_\tau}(\phi_1^* + \phi_2^* \tau) - \Psi_{\phi_\tau}(-\phi_1^* - \phi_2^* \tau)} \int_{-\phi_1^* - \phi_2^* \tau}^{\phi_1^* + \phi_2^* \tau} \zeta(\bar{\phi}_0, \tau) v_t^N(\theta, \bar{\phi}_0) d\Psi_{\phi_\tau}(\bar{\phi}_0) \\ &= \frac{1}{\int_{-\phi_1^* - \phi_2^* \tau}^{\phi_1^* + \phi_2^* \tau} P(\bar{\phi}_o, \tau) d\Psi_{\phi_\tau}(\bar{\phi}_o)} \int_{-\phi_1^* - \phi_2^* \tau}^{\phi_1^* + \phi_2^* \tau} P(\bar{\phi}_o, \tau) v_t^N(\theta, \bar{\phi}_0) d\Psi_{\phi_\tau}(\bar{\phi}_o). \end{aligned}$$

Next, we take expectations over θ :

$$E[v_\tau^N | \alpha] = \int_{-\infty}^{\infty} v_\tau^N(\alpha, \theta) d\Psi_\theta(\theta), \quad (\text{B.6})$$

where $\Psi_\theta(\theta)$ is zero-mean Normal with variance $(1 - \alpha)\sigma_\theta$. The final step is to take expectations over α . Let $f_\tau^N(\tau | \alpha) = 1 - F(\tau | \phi_1^*, \phi_1^*)$ denote the probability that a firm has not formed a spinoff by age τ , and let $f_\alpha(\alpha)$, $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, denote the population distribution of α . Then, the expected value of α among firms that have not spawned formed a spinoff by age τ is

$$E^N[\alpha | \tau] = \frac{1}{\int_{\underline{\alpha}}^{\bar{\alpha}} f_\tau^N(\tau | \alpha) f_\alpha(\alpha) d\alpha} \int_{\underline{\alpha}}^{\bar{\alpha}} \alpha f_\tau^N(\tau | \alpha) f_\alpha(\alpha) d\alpha, \quad (\text{B.7})$$

while the expected value of these firms is given by

$$E[v_\tau^N] = \frac{1}{\int_{\underline{\alpha}}^{\bar{\alpha}} f_\tau^N(\tau | \alpha) f_\alpha(\alpha) d\alpha} \int_{\underline{\alpha}}^{\bar{\alpha}} E[v_\tau^N | \alpha] f_\tau^N(\tau | \alpha) f_\alpha(\alpha) d\alpha. \quad (\text{B.8})$$

Derivation of $E[v_\tau^S | \alpha]$ and $E[v_\tau^S]$. This derivation is simpler. The first-passage problem is symmetric, so the average value of firms at the lower boundary is the same as at the upper boundary. Thus, we can fix ϕ_τ at the value of the upper boundary at time τ , $\bar{\phi}_1 = \phi_1^* + \phi_2^* \tau$, and ignore the lower boundary. Moreover, the terminal value of the Brownian motion is fixed at a single point, so there is no need to devise any weighting scheme to eliminate sample paths such as (d) in Figure B.1. Thus, we need only replace $\bar{\phi}_0$ with $\phi_1^* + \phi_2^* \tau$ in (B.4) to obtain $v_\tau^S(\alpha, \theta)$. Taking expectations over θ yields

$$E[v_\tau^S | \alpha] = \int_{-\infty}^{\infty} v_\tau^S(\alpha, \theta) d\Psi_\theta(\theta). \quad (\text{B.9})$$

Let $f_\tau^S(\tau | \alpha) = F'(\tau | \phi_1^*, \phi_1^*)$ denote the density of spinoff times conditional on α (from Theorem A.2). Then, by Bayes' rule, the expected value of α for firms that spawn a spinoff at age τ is given by

$$E^S[\alpha | \tau] = \frac{1}{\int_{\underline{\alpha}}^{\bar{\alpha}} f_\tau^S(\tau | \alpha) f_\alpha(\alpha) d\alpha} \int_{\underline{\alpha}}^{\bar{\alpha}} \alpha f_\tau^S(\tau | \alpha) f_\alpha(\alpha) d\alpha, \quad (\text{B.10})$$

and the unconditional expected value of these firms is

$$E[v_\tau^S] = \frac{1}{\int_{\underline{\alpha}}^{\bar{\alpha}} f_\tau^S(\tau | \alpha) f_\alpha(\alpha) d\alpha} \int_{\underline{\alpha}}^{\bar{\alpha}} E[v_\tau^S | \alpha] f_\tau^S(\tau | \alpha) f_\alpha(\alpha) d\alpha. \quad (\text{B.11})$$

Derivation of $E[v_\tau^\beta | \alpha]$ and $E[v_\tau^\beta]$. Because β -type firms produce no disagreements, the expected value of these firms conditional on θ is immediately obtained upon substituting $\alpha = 0$ into (7) and (8):

$$v_\tau^\beta(\alpha, \theta) = A - \frac{\theta^2 \sigma^2}{(\tau \sigma_\theta + \sigma)^2} - \frac{\tau \sigma_\theta^2 \sigma}{n(\tau \sigma_\theta^2 + \sigma)^2},$$

and taking expectations over θ yields

$$E[v_\tau^\beta | \alpha] = A - \frac{\sigma_\theta \sigma (\tau \sigma_\theta + n\sigma(1 - \alpha))}{n(\tau \sigma_\theta + \sigma)^2}. \quad (\text{B.12})$$

The expected value of α among $\beta(\alpha)$ -type firms is equal to the population mean, $E[\alpha] = \int \alpha f_\alpha(\alpha) d\alpha$, while the unconditional expectation of firm value is given by

$$E[v_\tau^\beta] = A - \frac{\sigma_\theta \sigma (\tau \sigma_\theta + n\sigma(1 - E[\alpha]))}{n(\tau \sigma_\theta + \sigma)^2} \quad (\text{B.13})$$

Subsection IV.C reports numerical evaluations of several of these equations using parameter values $n=5$, $\sigma_\theta=100$, $\sigma=100$, $k=1$, $\omega_n=0.2$, and $f(\alpha)=U[0.6,0.9]$.

Derivation of $E[\tilde{v}_\tau^S | \alpha]$. Given signals y and $\bar{s}_{n\tau}$, the strategy initially chosen by a spinoff launched when the parent is age τ is obtained upon setting $\omega_n = 1$ in (B.2). The initial value of the spinoff is consequently given by

$$\tilde{v}_\tau^S = A - \left(\theta - \frac{\tau \sigma_\theta (\bar{s}_{n\tau} + (1 - \alpha)y)}{(n(1 - \alpha) + \alpha)(\tau \sigma_\theta + \sigma)} \right)^2.$$

Substituting for $\bar{s}_{n\tau}$ using (B.3), setting $\bar{\phi}_1 = \phi_1^* + \phi_2^* \tau$, and taking expectations over y yields

$$\tilde{v}_\tau^S(\alpha, \theta) = A - \int_{-\infty}^{\infty} \left(\theta - \frac{\alpha \tau \sigma_\theta (1 - \omega_n)y - n\sqrt{k}(\tau \sigma_\theta + \sigma)}{\alpha(n - 1)(1 - \omega_n)(\tau \sigma_\theta + \sigma)} \right)^2 f_y(y | \phi_1^* + \phi_2^* \tau) dy.$$

Finally, taking expectations over θ yields

$$E[\tilde{v}_\tau^S | \alpha] = \int_{-\infty}^{\infty} \tilde{v}_\tau^S(\alpha, \theta) d\Psi_\theta(\theta). \quad (\text{B.14})$$

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