Intra-industry Spinoffs

Steven Klepper*

Carnegie Mellon University

Peter Thompson**

Florida International University

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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 show how the theory can explain the emerging empirical regularities.

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* Dept. of Social & Decision Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, email: sk3f@andrew.cmu.edu.

** Department of Economics, Florida International University, Miami, FL 33199, email: peter.thompson2@fiu.edu.

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I. Introduction

In 1901 Olds Motor Works introduced the one-cylinder Curved Dash Runabout. In the following year it became the first car to sell over 1,000 units in a single year. Olds had produced engines for many years and was headed by Ransom Olds, who was a talented inventor and businessman. To finance Olds Motor Works' entry into automobiles, Ransom Olds had to give up financial control of his company to Samuel Smith, a wealthy retired businessman who had made his fortune in copper and later in the organization of canals and railroads. Precision manufacturing had not yet been perfected in automobiles, and like other automobiles of its day Olds' cars had many defects that required fixing after they had been on the road. Ransom Olds' strategy was to the fix the defects in his shop, but Samuel Smith and his son Fred, who became active in the management of Olds Motor Works, wanted to improve the production process to lower the defect rate. They also wanted to develop larger cars than Ransom Olds favored. They began to experiment with new methods of manufacturing, which precipitated a fight with Ransom Olds that eventually led to his departure in 1904 at the peak of the company's success. Soon after, Ransom Olds was involved in a new startup, Reo, that was financed principally by individuals that had helped finance Olds Motor Works' entry into automobiles. Reo introduced a new, two-cylinder car in 1905 that reached the number three position in the industry by 1908, and it remained a leading automobile producer through 1923. In contrast, Olds Motor Works developed much larger and more expensive cars and soon fell out of the ranks of the leaders, only to be resurrected after the Smiths sold out in 1909 to the newly formed General Motors.[1]

This scenario of top employees leaving to form their own companies after internal disputes was played out repeatedly in the automobile industry. All told, approximately 20% of the 725 or so entrants into the automobile industry through the 1920s were founded by employees of incumbent automobile firms. We call these firms (intra-industry) spinoffs. Like Reo, many of the spinoffs in automobiles were very successful and disproportionately populated the ranks of the leading producers. In modern times, a remarkably similar process has characterized another high-tech industry, lasers. Internal disputes have led to

[1] See May [1977] for this account of developments at Olds Motor Works.

a steady stream of spinoffs. Like automobiles, the spinoffs have been distinctly successful, accounting for many of the leaders of the industry. Indeed, in many high tech industries, spinoffs are legion—in the semiconductor industry, for example, so many spinoffs can be traced back to one firm, Fairchild Semiconductor, they have been dubbed Fairchildren. And similar to autos and lasers, disagreements appear to have played a prominent role in the formation of spinoffs in a wide range of industries (Garvin [1983]).

The main purpose of this study is to develop a new theory of spinoffs that builds on the insights from autos, lasers, and other industries about the role of disagreements in the spinoff process. Various theories of spinoffs have been previously proposed. Some see spinoffs as parasites feeding off the innovative efforts of their parents whereas others see spinoffs as the font of innovation, compensating for the inertia that plagues incumbents. We contend that none of these theories can explain the full set of statistical regularities that are emerging from the empirical study of spinoffs in various industries, nor can they accommodate the tendency of spinoffs to result from disagreements. In contrast, we show that our theory, which is predicated on disagreements, can explain the main statistical regularities concerning spinoffs, including why spinoffs disproportionately come out of the leading firms, why they are superior performers, why better-performing firms tend to spawn better-performing spinoffs, why acquisitions enhance the likelihood of spinoffs, and why spinoffs are most likely when firms reach middle age. We also show how the model can accommodate certain patterns regarding spinoffs that differ across industries.

The management literature stresses the importance of firms forging a consensus about their strategy (e.g. Andrews [1971], Cyert and March [1963], Dess and Priem [1995]), but their have been few attempts to model formally the formation of a consensus and the emergence and consequences of disagreements among members of management teams.[2] An exception is recent work by Van den Steen [2004, 2005, 2006] on how disagreements due to agents holding different priors can affect incentive structures, the allocation of control, and the formation of management teams. In our work, we feature how disagreements can arise when some employees have superior information and abilities that are not recognized by incumbent management. Even though management teams may be formed

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[2] For reviews of the evidence concerning the relationship between firm performance and consensus formation, see West and Meyer [1998] and Rapert, Velliquette and Garretson [2002].

by individuals with similar opinions, subsequent disagreements are inevitable when members of a firm receive different signals about the best strategic direction for the firm and individuals are limited in their ability to evaluate new ideas. Spinoffs occur when the disagreements are of sufficient magnitude to justify the cost of forming a new firm and investors outside the firm are more able than incumbent management to evaluate novel ideas and abilities of employees. As such, spinoffs reflect a distinctive aspect of capitalism—decisions about which innovative ideas to pursue are decentralized to those most suited to make them.

The paper is organized as follows. In Section II we examine the role of internal disagreements in the formation of spinoffs in automobiles and lasers. We also discuss anecdotal evidence about the role of disagreements in inducing spinoffs in other industries. In Section III we lay out the main findings that have been accumulating from recent empirical studies of spinoffs and discuss the ability of prior theories to explain them. In Section IV we present our model and show how it can explain the main regularities characterizing spinoffs. In Section V we discuss additional implications of the model that accord with the patterns found in some industries and others that can help explain differences across industries. In Section VI we discuss alternative theories of spinoffs and their relation to our model. We also consider how our model can help explain the role of spinoffs in agglomerations and inform public policy related to spinoffs.

II. Spinoffs and Disagreements

Only recently have spinoffs been studied systematically. Perhaps the greatest challenge in studying spinoffs is to get inside the firms that spawn them to understand the circumstances behind their occurrence. The auto and laser industries provide unusual opportunities to do so. Hobbyists as well as scholars have long found the historical automobile industry to be of particular interest and a great deal has been written about the leading firms in the industry. These firms were the source of most of the prominent automobile spinoffs, and we use the literature on the leading firms to recount the circumstances behind their top spinoffs. In lasers, Klepper and Sleeper [2005] identified all the spinoffs in the industry--79 in total-- and collected information from public sources on each. Sherer [2006] followed this up with interviews of founders from most of the 79 spinoffs. We use this information to recount the circumstances behind representative spinoffs in each of the main types of lasers. We also discuss anecdotal evidence about the circumstances behind leading spinoffs in the disk drive industry, where spinoffs were also prominent, and about the impetus for spinoffs in a wide range of industries.

A. Automobiles[3]

As noted above, the first great firm in the industry was Olds Motor Works, which was located in both Lansing and Detroit, MI. It subcontracted the production of all its parts, including engines, which led to the formation nearby of the next three great producers in the industry in 1902 and 1903, Cadillac, Ford, and Buick. Olds and Buick, which was the centerpiece of the General Motors merger, each had seven spinoffs, and Ford and Cadillac each had four spinoffs, making them the most prolific parents in the industry. Among the 17 entrants after 1903 that made it into the ranks of the leading producers, 13 were spinoffs, including nine spinoffs of Olds, Cadillac, Ford, and Buick/GM. Table 1 summarizes information for these nine spinoffs.

Olds Motor Works had three leading spinoffs including Reo, which we have already reviewed. Next was E.R. Thomas Detroit, which was eventually renamed Chalmers when a controlling interest was sold to Hugh Chalmers, an ex-executive of National Cash Register. Soon after Ransom Olds left Olds Motor Works, the head of sales, Roy Chapin, and the chief engineer, Howard Coffin, proposed a new four-cylinder car that was a compromise between Olds' one-cylinder Curved Dash Runabout and the larger cars favored by the Smiths. The Smiths withdrew their support for the car at the last minute, leading Chapin, Coffin, and Frederick Bezner, the purchasing agent at Olds, to seek out support for the car elsewhere. They found it in E.R. Thomas, who himself was a producer of a high priced car through a company bearing his name. He provided initial financing and also marketed the new company's car through his own dealer network. E.R. Thomas-Detroit quickly became the twelfth leading producer and remained among the leaders for many years. In order to dilute control of the firm by E.R. Thomas, Coffin and Chapin got Hugh Chalmers to buy half of Thomas' stock and the company, renamed Chalmers, started marketing its own cars. It introduced a new four-cylinder car at a lower price and then

[3] This account is based on Klepper [2006a].

TABLE 1: 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)	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

Coffin proposed the design of a yet cheaper four-cylinder car to compete with the newly introduced Model T. Chalmers was not used to major changes in his product and allowed the car to be developed in a separate partnership. Although he purchased 15% of the stock of Hudson, which was organized by Chapin, Coffin, and two other Olds' employees to further develop Coffin's car, he soon traded it for the shares in Chalmers held by Coffin et al. Hudson's modest financing came primarily from J.L. Hudson, a wealthy department store magnate who was the uncle of one of the other ex-Olds founders. By 1910 Hudson was the tenth leading producer in the industry and it too remained among the ranks of the leaders for many years.

Both of Cadillac's leading spinoffs involved Alanson Brush. He was a talented engineer and inventor who had worked for the predecessor of Cadillac when it supplied engines and transmissions to Olds Motor Works. He solved an initial problem Olds had with its transmission and also improved the power of Olds' initial one-cylinder engine, which later was used by Cadillac. Brush clashed with Henry Leland, the head of Cadillac, over the control of his patents. He eventually left Cadillac with a $40,000 settlement and a pledge not to compete in autos for two years. Brush had designed a new small car while at Cadillac, but Henry Leland's preoccupation with precision manufacturing led Cadillac toward the production of ever larger and more expensive cars. Brush Runabout was 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 his ideas. Within two years it attained ninth place in the industry, but it was subsequently purchased in an abortive merger and expired within a couple of years. In the same year that Brush Runabout was formed, 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. Brush brought him the two-cylinder car he had designed at Cadillac. Oakland was soon acquired by General Motors when it was formed in 1908, and after 1910 its cars were consistently among the ranks of the leaders.

Ford's first leading spinoff, Hupp Motor Company, was formed by Robert Hupp, who initially worked for Olds Motor Works and then worked his way up to assistant superintendent at Ford. The impetus for Hupp's departure from Ford was unclear, but apparently Hupp aspired to be an entrepreneur and no evidence of a clash with Ford exists. Hupp Motor Company raised the capital it needed from advance sales of automobiles and initially produced a two-seater runabout that was considerably smaller than Ford's Model T. It was successful from the outset, attaining twelfth place in its first year and remaining among the ranks of the leaders for many years. Ford's other leading spinoff was formed by the Dodge brothers, who had been the primary producers of Ford's cars from its outset and held 10% of Ford's stock. Ford had taken on production of more and more of its parts and the Dodge brothers feared they would become obsolete. Consequently, they asked Henry Ford to buy them out, but after he dawdled they left to form their own company, financing it with $5 million that mostly came from dividends they had received from Ford. They capitalized on their experience with the Model T but incorporated new features Ford had spurned and produced a sturdier, more reliable car that needed no major changes over its first ten years. Dodge Brothers attained the number three position in the industry in its second year of operations in 1915 and was the number two producer in the industry when both Dodge brothers died in 1920.

Both of Buick/GM's leading spinoffs were founded by William Durant, who had catapulted Buick to success. He subsequently used Buick to form General Motors, which was the amalgamation of 27 separate organizations. GM's bankers were not satisfied with the way Durant integrated these companies and ousted him from GM. At the same time they dropped Buick's successful low-priced car and ceased its efforts to develop even smaller cars. Durant founded Chevrolet and two other firms mostly with his own funds to produce a range of cars. He soon concentrated Chevrolet's efforts on a smaller car that became the twelfth leading seller in 1912, one year after Chevrolet's formation, and eventually displaced the Model T as the number one selling car. In 1915 Durant used Chevrolet to regain control of GM, which he merged with Chevrolet. After another buying spree at GM, Durant lost control of GM for good and subsequently formed Durant Motors to produce a range of cars, similar to the strategy he engineered at GM. It 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.

A number of themes emerge from these nine spinoffs. First, all but Hupp involved some kind of disagreement, either about management, strategy, and/or technology. Second, again with the exception of Hupp, all the founders of the spinoffs were high-level employees. Third, all of the spinoffs produced distinctive cars, although in many instances related to their prior efforts. Last, the spinoffs raised capital from other experienced auto and carriage men, from past financiers of their successful ventures, from relatives, and in two instances self-financed. The outsiders that provided finance were well positioned to evaluate either the initial ideas or abilities of the founders of the spinoffs.

B. Lasers

Spinoffs accounted for a similar percentage of entrants in lasers as automobiles and as a group were distinctly successful. Klepper and Sleeper [2005] distinguished eight main types of lasers based on their lasing material. For each, they provided a synopsis of a representative spinoff. Table 2 summarizes information for these eight spinoffs based on Klepper and Sleeper [2005], supplemented by information collected by Sherer [2006].

The first spinoff, Uniphase, is illustrative. Its parent, Spectra Physics, studied various ways to improve its Helium Neon (HeNe) laser, which is the laser 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 2: 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 2 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 did not aggressively pursue. 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 Omnichrome to continue producing the HeCd lasers.

All of these cases involve disagreements about technology and/or markets. Sherer [2006] found that most of the 79 spinoffs in lasers were prompted by some kind of disagreement, often about technology or markets. The other two spinoffs both followed acquisitions, which Sherer [2006] also found was a common impetus in the laser industry for disagreements that led to spinoffs. One difference from autos is that most of the laser spinoffs in Table 2 involved technical employees that were not high-level employees, which Sherer [2006] found was generally true among laser spinoffs.

C. Other Industries

Another industry where spinoffs have been studied is disk drives (Franco and Filson [2000], Agarwal et al. [2004]). Spinoffs were extraordinarily successful in disk drives, accounting for nearly all the revenues generated by *de novo* entrants (Franco and Filson [2000, p. 18]). Moreover, from 1977 to 1997 five "architectural" innovations occurred in disk drives. Each reduced the size of disk drives and opened up new markets, eventually displacing the larger drives in all uses. Early entry into each of these smaller drives was dominated by spinoffs (Franco and Filson [2000]). Christensen [1993] recounts how the leading incumbents introduced prototypes of the smaller drives but declined to commercialize them when their customers showed little interest in the new drives. Engineers that worked on the prototypes then left in frustration to form their own spinoffs to commercialize the new drives. Thus, like in autos and lasers, the leading spinoffs were formed as the result of strategic disagreements within the leading incumbent firms.

The spinoffs we reviewed in autos, lasers, and disk drives are representative of a common theme echoed by founders of spinoffs in diverse industries—they left their prior employers in frustration after their ideas were not heeded or were rejected (Garvin [1983]). As we will see below, spinoffs as a group have repeatedly been found to be exemplary performers, suggesting that on average their ideas had merit. We now turn to consider various statistical regularities that are emerging about spinoffs and the ability of prevailing theories to explain the regularities.

III. Regularities and Spinoff Theories

Spinoffs have been studied in a number of new, innovative U.S. manufacturing industries, including the historical auto (Klepper [2006a, 2006b]) and tire (Buenstorf and Klepper [2005]) industries and the modern semiconductor (Brittain and Freeman [1986]), disk drive (Franco and Filson [2000], Agarwal et al. [2004]), laser (Klepper and Sleeper [2005], Sherer [2006], Sleeper [1998]), medical device (Chatterji [2005]) and biotechnology (Stuart and Sorenson [2003], Mitton [1990]) industries. Spinoffs have also been studied in U.S. law firms (Phillips [2002]) and Australian and New Zealand wine producers (Roberts et al. [2006]). In all of these industries, spinoffs were prominent and accounted for a substantial fraction of entrants. The focus of these studies is on the rate at which firms spawn spinoffs and the performance of 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 spinoffs across the entire Danish private sector.[4]

The main findings of the studies are summarized in terms of five regularities. First, in autos, tires, semiconductors, disk drives, and lasers, better-performing firms, proxied by longevity, market share, quality of technology, breadth of product offerings, and/or earlier entry, have higher spinoff rates.[5,6] Second, in autos, biotechnology, lasers, and semiconductors, firms acquired by non-industry incumbents have higher spinoff rates around

[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 lasers, 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. Franco and Filson [2000] and Agarwal et al. [2004] 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 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 [2000] it negatively, but insignificantly, affects the firm spinoff rate).

the time of their acquisition, while in autos and lasers (but not biotechnology or semiconductors) firms acquired by industry incumbents also have comparably higher spinoff rates around the time of their acquisition. Relatedly, in semiconductors firms that hired a CEO from outside the company have higher 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, and law firms (but not disk drives or tires), as firms age (in terms of years of production in the industry) the spinoff rate first rises and then falls (after around age 14).[7] Fourth, in autos, disk drives, lasers, medical devices, tires and wine, the performance of spinoffs, proxied by longevity, size, scope, years to first VC funding or pre-money valuation, 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 survive longer than other new entrants. Fifth, in autos, disk drives, law firms, and tires (but not lasers) the better the performance of the parent firm, proxied by longevity, market share, and/or quality of technology, then the better the performance of the spinoff.[8] Furthermore, Chatterji [2005] and Sherer [2006] find that in medical devices and lasers respectively the extent of knowledge transfer and/or overlap between parent and spinoff does not influence the performance of the spinoff, proxied by longevity and years to first funding or pre-money valuation.

The five regularities are summarized in Table 3 in the order they will be addressed in the discussion of the theoretical model.

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[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] 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 [2000] did not find that spinoffs from parents with better technology survived longer (if anything, they survived shorter).

TABLE 3: Spinoff Regularities

1	The probability of a spinoff first rises and then falls with firm age, making middle age the most likely time for spinoffs.
2	Spinoffs perform better than other *de novo* entrants and comparably if not better than diversifying entrants.
3	Better-performing firms have better-performing spinoffs.
4	Better-performing firms spawn spinoffs at a higher rate.
5	Firms that are acquired have a higher rate of 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 spinoffs.

How well can these regularities and the influence of disagreements on spinoffs be explained by prior theories of spinoffs? These theories fall into three main camps. In the first, an employee forms a spinoff to exploit a discovery that the employer financed but could not establish property rights over. Various types of information asymmetries make it more profitable for the employee to implement the discovery in his own firm rather than reveal it to his employer even if it can be more profitably developed by the employer.[9] In the second type of theory, the discovery is common knowledge but is less profitable to the incumbent than a spinoff, either because the incumbent has limited ability or capacity to manage diverse projects or because it would cannibalize the incumbent's rents.[10] In the third type of theory, employees learn from their employers about

[9] See Anton and Yao [1995], Wiggins [1995], Bankman and Gilson [1999], Gromb and Scharfstein [2002], and Amador and Landier [2003]. Common themes are (i) firms cannot commit to a contingent contract that adequately rewards the employee for a 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.

[10] See Pakes and Nitzan [1983], Tushman and Anderson [1986], Henderson and Clark [1990], Christensen [1993], Hellman [2002], Klepper and Sleeper [2005], and Cassiman and Ueda [2006].

how to profitably compete, which they can best exploit by starting their own firm.[11]

None of these theories seems to capture fully the basic process underlying spinoffs. The first theory predicts that founders of spinoffs will not reveal their ideas to their employers, but the evidence suggests that the founders of spinoffs not only reveal their ideas to their employers but leave only after their ideas are rejected. The second type of theory is consistent with employers rejecting the ideas of spinoff founders if established firms have limited ability to manage ideas that do not fall within their core activities. However, most of the disagreements we reviewed in autos and lasers were central to the employer's mission. Moreover, if spinoffs were the result of some kind of limited ability of incumbent firms, then why would spinoffs be more likely to be spawned by better-performing firms and why would better-performing firms have better-performing spinoffs? The third theory can explain these two patterns, but it suggests that spinoffs do similar things to their parents that they learned from them. Yet spinoffs appear to pursue ideas their parents reject. Moreover, none of the theories can readily address why acquisitions and CEO changes seem to raise firm spinoff rates and why in various industries spinoffs are more likely when firms are middle-aged.

IV. A Model of Disagreements and Spinoffs

Our model uses the framework of Bayesian learning developed in Jovanovic and Nyarko [1995]. For simplicity, firm strategy is reduced to a single dimension. The firm must choose a strategy x to maximize the value of the firm, which is given by $v = A - (x - \theta)^2$, where θ is an unknown target. The firm is infinitely-lived and composed of $i = 1, 2, \ldots, n$ decision makers that remain the same over time except for the possibility of an individual leaving to found a spinoff. Each decision maker i combines information based on Bayesian principles to form a subjective distribution for θ in each period t with mean θ_{it} and variance σ_{it}. Given individual i's subjective distribution for θ at time t, the strategy that maximizes the expected value of the firm is to set $x = \theta_{it}$, yielding an expected payoff of $A - \sigma_{it}$.

[11] See Franco and Filson [2000] and Agarwal et al. [2004].

Let the firm's choice for x at time t, $\theta_t = \Sigma\omega_i\theta_{it}$, be a weighted average of the choices of each individual, where $\Sigma\omega_i = 1$ and the weights ω_i reflect 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, and his expectation of the firm's value is

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

where $\Delta_{it} = \theta_{it} - \theta_t$, denotes i's disagreement with the firm's strategy. Expectations are taken with respect to i's subjective distribution for θ and in the third line use was made of $E_{it}[(\theta_{it} - \theta)] = 0$, which follows from the fact that Bayesian subjective distributions are unbiased. 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 individuals do not want to be a part of a firm whose strategy they do not believe in and will leave to start their own firm whenever $\Delta_{it}^2 > k$. Thus, if an individual disagrees sufficiently with the firm's strategy, he will leave and start a spinoff.

Note that disagreements depend only on differences in the means and not the precision of individuals' beliefs. We generate these differences through the following mechanism. One individual is assumed to have superior information or superior ability to evaluate information about θ. However, the other decision makers in the firm do not recognize this, reflecting their limited ability to evaluate the ideas and abilities of others. All members of the firm communicate their views to each other, which enables them to learn each other's information and thus to tap the information possessed by all members of the firm. But because they have different perceptions about the quality of the information possessed by individuals, they weigh the information of individuals differently, leading to disagreements and possibly spinoffs. For simplicity, the model allows for at most one spinoff, but it could be readily generalized to allow for multiple spinoffs by providing more than one individual with unrecognized superior information/ability. Our analysis focuses on the factors that condition the probability of a firm spawning a spinoff.

This is modeled formally as follows. At time 0, each individual has a prior distribution for θ based on information about θ generated before the formation of the firm. We assume the mean of each individual's prior is unbiased in the sense that it is drawn from a (normal) distribution with a mean of θ. The firm is assumed to be formed of like-minded individuals that all have the same prior mean for θ. The closer this mean is to θ then the better the initial calibration of the firm. We focus on the evolution of disagreement within a single firm, so without loss of generality let this mean be 0. Let the variance of the prior distribution of θ be σ_θ for individuals i =1,2,…, $n - 1$ and $\alpha\sigma_\theta$ for individual n, where $0 < \alpha \leq 1$. This corresponds to individual n potentially having better prior information or a better ability to evaluate information about θ. In each period t, individuals are also assumed to receive a private and noisy signal $s_{it} = \theta + \varepsilon_{it}$, where the ε_{it} are independent draws from a normal distribution with mean 0 and variance σ_ε for individuals i = 1, 2, …, $n - 1$ and $\alpha\sigma_\varepsilon$ for individual n. Again, this reflects the potentially better information or better ability to evaluate information of individual n. If $\alpha < 1$, individual n has more precise prior information and also signals than the other decision makers. We assume, however, that only individual n knows this. All other decision makers believe that the variance of everyone's prior is σ_θ and the variance of everyone's signals is σ_ε.

If α were common knowledge, repeated transmission and updating of posterior beliefs would fully reveal the private signals of each individual, and disagreement would not be possible (Aumann [1976], Geanakoplos and Polemarcharkis [1982]). There are two ways to induce disagreements when individuals i=1,2, . . ., $n - 1$ are mistaken about the precision of n's signals. First, the repeated exchange of beliefs will lead them to miscalculate n's signals. Alternatively, one can assume that communication involves the direct transmission of the signals received, and all except n treat n's signals as noisier than they really are. Both induce differing posterior beliefs, and for convenience we take the latter approach.

Let $\overline{s}_{it} = t^{-1}\sum s_{it}$ denote the mean signals of individual i, which are observed by everyone in the firm. Individuals i = 1, 2, …, $n - 1$ weigh everyone's information equally based on their beliefs about the precision of the information, which yields a subjective distribution for θ at time t with posterior mean

$$\theta_{it} = \frac{t\sigma_\theta \sum_{i=1}^{n} \overline{s}_{it}}{n\left(t\sigma_\theta + \sigma_\varepsilon\right)}, \quad i = 1, 2, \ldots, n-1. \tag{2}$$

In contrast, individual n weighs his own information more than anyone else's, yielding a posterior mean of

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

where $\lambda \equiv n/[(n-1)\alpha + 1] \geq 1$.

Because these means are different, individual n's preferred strategy will differ from that of the firm, which is a weighted average of the posterior means of all individuals. Using $\theta_t = \Sigma\omega_i\theta_{it}$ and equations (2) and (3), the difference between n's optimal strategy and the strategy chosen by the firm is

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

Individuals $i = 1, 2, \ldots, n-1$ have the same views about what the firm should do, but individual n 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. Note that if somehow the mean of everyone's signals were the same, then Δ_{nt} would equal 0. Thus, disagreements depend critically on individuals getting different signals. Although disagreements are driven by *differences* in the values of signals, their actual values, as well as the realized value of θ, affect the value of the firm: 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. But 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.

A. The spinoff probability

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

$$T = \min_{\tau} \left\{ \tau : \Delta_{n\tau}^2 \geq k \right\}. \tag{5}$$

Solving for this distribution is complicated, but we can make headway concerning the probability a firm ever spawns a spinoff by analyzing Δ_{nt}. Equation (4) indicates that Δ_{nt} is a linear function of the signals received by all individuals, each of which is normally distributed. Consequently, Δ_{nt} is also normally distributed, and it is readily verified from (4) that Δ_{nt} has zero mean and variance

$$E\left(\Delta_{nt}^2\right) = \frac{(1-\omega_n)^2 (n-1)(1-\alpha)^2 t\sigma_\theta^2 \sigma_\varepsilon}{n^2 \left(t\sigma_\theta + \sigma_\varepsilon\right)^2 \left(1+\alpha(n-1)\right)}. \tag{6}$$

Thus, as of the time the firm is formed, the probability in period *t* that $\Delta_{nt}^2 > k$ is completely determined by (6). The larger the value of $E(\Delta_{it}^2)$ in (6) then the greater the probability in period *t* that $\Delta_{nt}^2 > k$ and a spinoff occurs. It follows from equation (6) that $E(\Delta_{it}^2)$ equals zero at time 0, hence there is no chance of a spinoff at time 0. Intuitively, the firm is formed of like minded individuals and so at time 0 there is no chance of a disagreement. Equation (6) also indicates that as *t* approaches infinity, $E(\Delta_{it}^2)$ must approach zero. Intuitively, if individuals receive enough signals then they will all learn θ and there will be no chance of a disagreement. Consequently, asymptotically the probability of a spinoff must approach zero. Therefore, the probability of a spinoff must be small at very young and very old ages and peak at middle age, consistent with the first regularity summarized in Table 3.

Differentiating (6), it is readily verified that the variance of Δ_{nt} in every period *t* is decreasing in α and ω_n. Intuitively, disagreements arise only because of the unrecognized information/ability of the n^{th} individual. The greater is this unrecognized information/ability (i.e., the lower is α), the more severe is the expected disagreement in every period. Furthermore, the more influence the n^{th} individual has on the firm's decision then the more the firm's strategy will resemble his preferred strategy. Therefore, the lower is the influence of the n^{th} individual (i.e., the lower ω_n) then the greater is the expected disagreement in every period.

We verify below that the probability a firm will ever spawn a spinoff is strictly less than one and anything that increases the variance of Δ_{nt} in every period will increase the probability of a firm ever spawning a spinoff. Therefore, the probability a firm ever spawns a spinoff will be greater the better the information/ability and the lower the influence of the n^{th} individual.

B. Parent quality, spinoff quality, and the probability of a spinoff

The objective expected value of the firm at time t is given by

$$E_t[v \mid \theta] = A - E_t\left[\left(\theta_t - \theta\right)^2\right], \tag{7}$$

where the expectation is based on the actual distributions of s_{it} for each individual. The expected value of a spinoff can be computed directly from (7) with ω_n set equal to 1. In the appendix, we show that $\partial E_t[v \mid \theta] / \partial \omega_n > 0$, which implies that the expected value of the spinoff is greater than the expected value of its parent. Intuitively, the spinoff optimally weights the information of the n^{th} individual whereas the firm does not. We also show in the appendix that $\partial E_t[v \mid \theta] / \partial \alpha < 0$ and $\partial E_t[v \mid \theta] / \partial(\theta^2) < 0$, which imply that the better is the information of the n^{th} individual and the closer the realization of θ to the prior mean of all the members of the firm, then the better is the performance of both the spinoff and its parent. The expected fate of the spinoff and parent are thus tied together through two channels. First, they share the same prior mean for θ, and parents with a mean close to [far from] θ will spawn spinoffs of high [low] initial quality. Second, they are linked through individual n's ability because gifted individuals that found high-quality spinoffs also contribute to the performance of their parents. Although this contribution is greater before they depart, there are residual effects after departure because the parent company enjoys the durable benefits of the more accurate signals received by individual n.

We established previously that the better the unrecognized ability/information of the n^{th} individual then the greater the probability a firm will ever spawn a spinoff. We now see that the greater this unrecognized ability/information then the greater the expected value of the firm as well. It follows directly that the probability of spawning a spinoff will be greater for higher quality firms, consistent with the second regularity in Table 3. It also follows that the parents of spinoffs will on average be better quality firms. With the expected value of spinoffs greater than that of their parents, on average spinoffs will also be higher quality firms, consistent with the third regularity in Table 3. Last, with the expected value of parents and spinoffs directly related, it follows that better quality firms will have better quality spinoffs, consistent with the fourth regularity in Table 3.

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

The last regularity in Table 3 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 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. We established previously that the lower the influence of the n^{th} individual then the greater the probability of a firm ever spawning a spinoff. Therefore, if the decision-making authority of all individuals, including the n^{th} individual, is reduced after a acquisition or change in the CEO, then this will increase the probability a firm spawns a spinoff. Thus, acquisitions and changes in the CEO, especially when the acquirer is from another industry or the CEO is from another firm, might be expected to increase the probability of a spinoff, consistent with the last regularity in Table 3.

D. The first passage problem and the spinoff hazard

We can provide further insight into the spinoff process and provide formal grounding for our claims by analyzing the first passage problem given by (5). This is a difficult problem for two reasons. The first is that the stochastic process governing Δ_{nt}^2 is quite complicated. Δ_{nt}^2 is a correlated chi-square random variable whose expected value changes over time according to (6). The second difficulty is that in discrete time the absorbing boundary, k, may be overshot.

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

$$\phi_t = \Delta_{nt}\sqrt{\frac{t}{\mathrm{var}(\Delta_{nt})}}$$

$$= \frac{\left(t\sigma_\theta + \sigma_\varepsilon\right)n\sqrt{1+\alpha(n-1)}}{(1-\alpha)\sigma_\theta\sqrt{\sigma_\varepsilon(n-1)(1-\omega_n)}}\Delta_{nt}\ . \tag{8}$$

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, . . . , is a standard zero-drift Wiener process with boundary condition $\phi(0)=0$. The absorbing barrier for Δ_{nt}^2 is k. There are two corresponding barriers for $\phi(t)$, obtained by replacing Δ_{nt} with $\pm\sqrt{k}$ in (8), given by

$$\phi^*(t) = \pm\left(\phi_1^* + \phi_2^* t\right), \tag{9}$$

where

$$\phi_1^* = \frac{n\sqrt{\sigma_\varepsilon(1+\alpha(n-1))k}}{(1-\alpha)\sigma_\theta\sqrt{(n-1)(1-\omega_n)}} \tag{10}$$

and

$$\phi_2^* = \frac{n\sqrt{(1+\alpha(n-1))k}}{(1-\alpha)\sqrt{\sigma_\varepsilon(n-1)(1-\omega_n)}}\ . \tag{11}$$

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

$$T = \min_t\left\{t : \left|\phi(t)\right| \geq \phi_1^* + \phi_2^* t\right\}. \tag{12}$$

Note that for α = 1 or ω_n = 1 the absorbing barriers are infinitely far from the origin and hence unattainable by any sample path.

Equation (12) 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. Figure 1 illustrates. The transformed problem is easier than the original to analyze for three reasons. First, the continuous time transformation eliminates overshooting of the barriers.

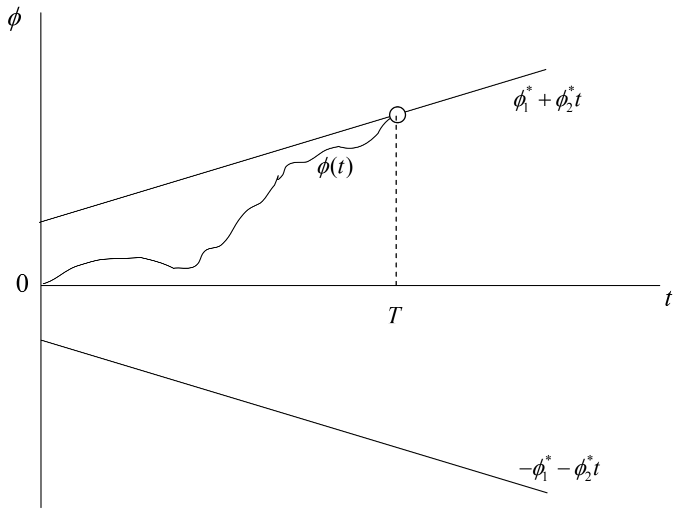

Figure 1. The first passage problem

Second, there are some known results for first-passage distributions for Weiner processes. Third, all parameter changes affect the problem only by moving the barriers; the sample path of the stochastic process is invariant to parameter changes.

Our first result, which is proved in the appendix, verifies that the probability of a firm ever spawning a spinoff, $\lim_{T\to\infty} F\left(T \mid \phi_1^*, \phi_2^*\right)$, is strictly less than 1. This probability depends on ϕ_1^* and ϕ_2^* only through their product, $\phi_1^*\phi_2^*$. From (10) and (11),

$$\phi_1^*\phi_2^* = \frac{n^2\left(1+\alpha(n-1)\right)k}{(1-\alpha)\sigma_\theta(n-1)(1-\omega_n)}, \tag{13}$$

and as $\lim_{T\to\infty} F\left(T \mid \phi_1^*, \phi_2^*\right)$ is strictly decreasing in the product, $\phi_1^*\phi_2^*$, it is readily confirmed that the probability of a firm ever spawning a spinoff is decreasing in α and ω_n, as we discussed earlier. It is also decreasing in k, as would be expected.

We can go further and analyze the determinants of the spinoff hazard and how it evolves over time. To do this, we need the first passage distribution for arbitrary T as given in (5). While this is a known distribution, it is complicated and relegated to Theorem 1 in the appendix. A quick inspection of Theorem 1 will make it obvious that numerical analysis is necessary. Our analysis suggests that a representative hazard function,

$h(t) = F'(t)/(1 - F(t))$, begins at zero, then rises monotonically to a peak and then falls monotonically toward zero. This corresponds with our earlier discussion of how $E(\Delta_{it}^2)$ initially equals zero, then becomes positive, and then asymptotically approaches zero.

Using numerical analysis, it can be verified that the hazard of spinoff formation, $h(t)$, is: (i) decreasing in α, ω_n, and k for all $t > 0$; (ii) increasing in σ_θ for all $t > 0$; and (iii) there exists a $\tau > 0$ such that $h(t)$ is decreasing [increasing] in σ_ε for $0 < t <$ [>] τ. The intuition behind these results is provided in Figures 2 and 3. Figure 2 illustrates the effects of an increase in α, ω_n, or k. Both $|\phi_1^*|$ and $|\phi_2^*|$ are increasing in these parameters, so the barriers move away from the origin at $t = 0$ and become steeper, indicated by a shift from **AA** to **BB**. A reduction in σ_θ shifts the barrier out without altering its slope, and so unambiguously increases the hazard of spinoff formation. In contrast, a reduction in σ_ε reduces $|\phi_1^*|$ and increases $|\phi_2^*|$. This shifts the barriers as shown in Figure 3, which makes early hits to the barriers more likely, and later hits less likely. Although the probability that the parent company ever spawns a spinoff is independent of σ_ε (this follows directly from (12), which is independent of σ_ε), if it does spawn one it is likely to do so earlier. A reduction in σ_ε 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 t small [large].

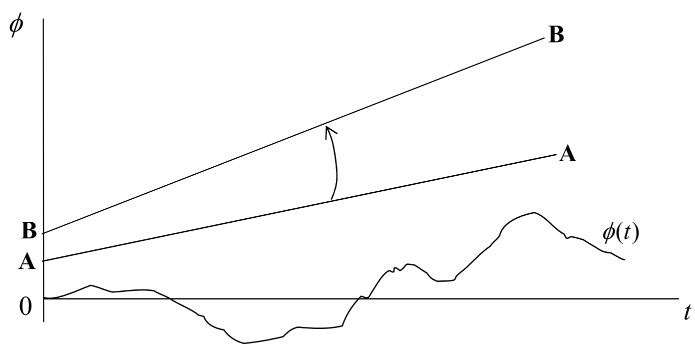

FIGURE 2. An increase in α, ω_n, or k causes the absorbing barriers to move from **AA** to **BB**. Only the upper barrier is shown.

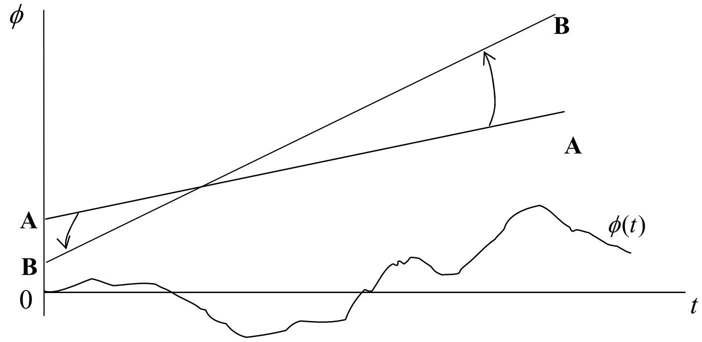

FIGURE 3. A reduction in σ_ε causes the absorbing barriers to move from **AA** to **BB**.

We also illustrate the effect of an acquisition or change in the CEO on the spinoff hazard in Figure 4. An acquisition or change in the CEO at time τ shifts the absorbing barriers in and reduces the absolute value of their slopes. Some sample paths for $\phi(t)$ are also illustrated. An individual n that found himself at point **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 **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.

V. Further Implications of the Model

In summary, the model readily accommodates the observed influence of disagreements on spinoffs and it explains the five regularities regarding spinoffs. We now consider other implications of the model and how they help explain other findings about spinoffs.

If a spinoff occurs, in the model it initially uses the same information as its parent to formulate its strategy. Consequently, at the time of their formation spinoffs should have more in common with their parents than other firms in their industry. Furthermore,

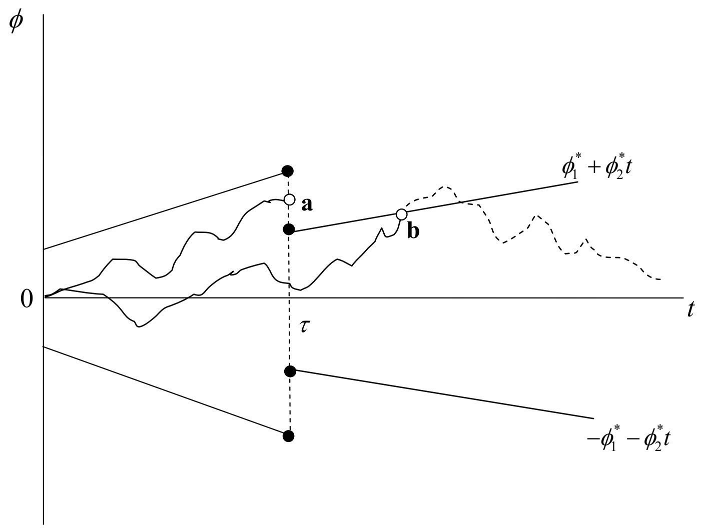

FIGURE 4. The effect on the absorbing barriers of decreased influence of the n^{th} individual

because both parent and spinoff rely on the same information, their performance will be further linked. The closer θ is to zero, and the closer the mean of the signals received is to θ, the better the ex post performance of parents and their spinoffs. This will reinforce the positive correlation between the expected performance of parents and spinoffs that stems from the influence of the spinoff founder on both parent and spinoff.

Both of these predictions are consistent with the evidence compiled for lasers, autos, and disk drives. Breaking lasers into eight broad groups and a catchall category, Klepper and Sleeper [2005] found that nearly all spinoffs initially produced the same type of laser as their parent, which largely persisted when lasers were disaggregated into many more categories (Sherer [2006]). In automobiles, the cars initially produced by the leading spinoffs shared many features with those produced by their parents. Indeed, many of the leading spinoffs exploited ideas they had initially developed while working for their parents. The disk drive industry provides support for the link between the performance of parents and spinoffs due to shared technology. Franco and Filson [2000] found a positive correlation between the areal density of the disk drives of parents and their spinoffs, where areal density measures the amount of information that can be stored per square inch of a disk. Moreover, firms whose disk drives had greater areal density survived longer, suggesting that the fate of parents and spinoffs was tied through the technology they each employed.

The fact that parents and spinoffs would be expected to overlap does not mean that the extent of the overlap will condition the performance of the spinoffs. Indeed, in the model spinoffs do not derive their superior average performance from any overlap with their parents. Rather, their superior performance stems from pursuing good ideas their parents are not willing to pursue, which was consistent with the spinoffs in autos, lasers, and disk drives that we reviewed. Consistent with this prediction of the model, both Chatterji [2005] and Sherer [2006] found that in medical devices and lasers respectively the degree of technical and market overlap between parents and their spinoffs was not predictive of the performance of spinoffs.

In the model, better-performing firms spawn more and better-performing spinoffs because they are both influenced by the ideas/abilities of the founders of the spinoffs. The influence of these founders on the parents depends, though, on their influence in the decision making process in the parent. We saw that the level of the founders of spinoffs on average was considerably lower in lasers than autos, perhaps because the knowledge held by top decision makers was either not that distinctive or was more accessible to lower-level employees in lasers than autos. Either way, if lower-level employees have less influence on the decisions of their employers, then the model would predict a weaker link between the performance of parents and both their spinoff rate and the performance of their spinoffs. Consistent with this, these links were strong in autos but in lasers the performance of parents and spinoffs was not related (Sherer [2006]) and after controlling for the breadth of firms, better firms did not have higher spinoff rates (see footnote 5).

The model predicts that lower-level employees are more likely to found spinoffs, all else equal. It also predicts that the greater the decision making influence of a better informed/able individual, the smaller the value of α that will be required to induce a spinoff. In turn, the lower the value of α then the greater the expected performance of the spinoff. Thus, higher level founders would be expected to found better-performing spinoffs, but this has nothing to due with their inherent abilities. Furthermore, we would also expect the disagreements behind spinoffs founded by higher-level employees to be more pronounced. These predictions resonate with the full set of spinoffs of the top four automobiles firms, which includes 12 additional spinoffs beyond those listed in Table 1. The historical record is not nearly as detailed for these firms as the top spinoffs, but it is striking how many lower-level employees were involved in their formation and how uneventful their motivations seem to have been. For example, Olds' had four other, lesser spinoffs founded by an engineer/tester, draftsman, director/secretary, and purchasing agent and Cadillac's other spinoff was founded by a sales agent.[12] Ford and GM's lesser spinoffs involved some prominent individuals, but overall the founders of the lesser spinoffs of the top four firms are much less impressive than the founders of their top spinoffs. Moreover, apart from some of Ford's and GM's lesser spinoffs, most of the lesser spinoffs seemed to have been founded to pursue modest technical ideas that did not seem to elicit much controversy in their parent firms.

In the discussion of the five statistical regularities, we noted that disk drives and tires did not exhibit an inverted u-shape with respect to firm age for the hazard of spinoff formation. Indeed, in both industries age had no effect on the hazard of a spinoff. This may be due to notable technical developments that occurred in both industries that fundamentally altered the strategic landscape. The predicted shape of the spinoff hazard depends critically on the target, θ, not changing over time, which leads to a monotonic increase in the precision of individual beliefs. Alternatively, suppose technical developments repeatedly shift the target. These developments, especially major ones that are likely to have a large impact on the optimal strategy, can induce reductions in precision at random intervals that prevent the spinoff hazard from eventually declining. As we found for the effect of acquisitions, sufficiently important technological developments can induce a marked spike in spinoffs around the time of the innovation.

These predictions are consistent with the limited information we have about spinoffs in disk drives and tires. Disk drives went through successive 'architectural" innovations that not only opened up major new markets but eventually displaced the older drives. Moreover, these developments led to disagreements that in turn soon triggered spinoffs that ended up pioneering the new drives. In tires, in the 1910s a new tire was introduced that ultimately greatly increased the longevity of tires and the comfort of the ride. It took

[12] Cadillac's fourth spinoff was Ford Motor Company, reflecting that Cadillac was founded by Henry Ford (and originally named the Henry Ford Company).

about ten years for these tires to catch on, but eventually they took over the entire industry. The longevity of tire producers depended closely on how quickly they adopted the new tires (Klepper and Simons [2000]). More important, the rate of spinoffs in tires, reflected by the fraction of entrants that were spinoffs, increased markedly after the new tire design began to diffuse widely. This occurred in the 1920s when the leading tire firms were well past middle age, which may have interrupted the decline in the hazard of spinoffs predicted by the model (with no change in the target).

In the model, a firm either adopts the suggestions of a decision maker or it risks the chance of a spinoff. While few intermediate cases occurred in either autos or lasers, some firms actually adopt an intermediate strategy in which they sponsor their own "corporate" spinoffs. Interpreted from the vantage point of the model, corporate spinoffs can be thought of as a compromise in which the ideas of an employee are heeded but the parent retains some ownership and control over the new entity. In terms of the model, the employee is given greater influence over the firm's strategy, which will mitigate disagreements and thus conceivably forestall a spinoff. The model implies that the more control a firm retains over its spinoffs then the worse the performance of the spinoffs—the spinoff's expected performance is greatest when the individual with the superior ideas/abilities is given full control over the spinoff. Chesbrough's [2003a] findings regarding Xerox's corporate spinoffs support this prediction. Xerox constituted a number of corporate spinoffs, some of which, such as Adobe, became quite successful. Chesbrough found that the greater Xerox's involvement in its corporate spinoffs in terms of the share of the spinoff's equity it owned, whether the spinoff's CEO came from Xerox, and whether the spinoff marketed its product through Xerox, the worse the performance of the spinoff.

The model predicts that on average spinoffs will outperform their parents and also weaken the performance of their parents by removing an individual with superior information/insights. Both hypotheses will be hard to test if firms develop enduring advantages, as Klepper [1996] and Sutton [1998] theorize is characteristic of more innovative, "high-tech" industries. Examples can be found, however, that support both conjectures. In the disk drive industry, spinoffs were in the forefront of the development of the new, smaller disk drives, which repeatedly enabled them to displace their parents as the industry leaders (Franco and Filson [2000], Christensen [2003]). Phillips [2002] found that among Silicon Valley law firms in the period 1946-1996, spinoffs increased the failure rate of their parents. Moreover, the increase was more pronounced when the spinoff founder was a more prominent employee (a partner), which is consistent with the model.[13]

Most of the leading automobile spinoffs were not financed by their founders. This makes sense in the context of the model only if the financiers were better able to evaluate the ideas of the spinoffs than their parent firms. A reflection on the management of the top automobile firms provides some insight into why this might well have been true (Klepper [2006a]). As we noted, control of Olds Motor Works passed to the Smiths, father and son, but neither had any experience in manufacturing and Olds soon floundered under their direction. It is not hard to understand how they might not have been good judges of the ideas proposed by their employees. Henry Leland, who headed Cadillac, was a rigid man whose entire career had been spent in manufacturing, first as a machine tool salesman and later as a partner in a firm that manufactured products for other firms. Cadillac was founded by Henry Ford as the Henry Ford Company but soon floundered, and Leland was brought in to advise the investors. Leland had no knowledge or experience in marketing, and it is easy to envision how limited he would have been in evaluating ideas for novel automobiles. Henry Ford was notoriously rigid and arbitrary regarding many of his views. Most of his career he was only interested in building a low-cost car for the masses and was unresponsive to any ideas about other kinds of cars or even to suggestions about how to improve the Model T. Last, for many years GM was run by its founder, William Durant. He was a brilliant organizer but was less interested and adept at management. He frustrated many of his employees, including Walter Chrysler, who rose to become head of Buick but eventually refused to work for Durant and went on to greater heights. It is not hard to envision Durant's decision making limitations either.

Each of these individuals was great in his own way, but almost the very same things that made them great—a kind of singular focus—made them unreceptive to new ideas regardless of their merit. At the same time, the men who financed the spinoffs were experienced

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[13] Assuming more prominent employees have greater decision making influence, the model predicts that the departure of an employee with superior information/abilities will have more effect on the performance of the firm the greater the decision-making influence of the employee.

auto and carriage producers, past financiers of successful founders, and relatives. It is also not hard to envision how they might have been better able to evaluate the ideas and abilities of the spinoff founders than their incumbent management.

The role these financiers played historically in the automobile industry is today often played by venture capitalists, who themselves may have previously worked in the industry in which they specialize (i.e., they too were spinoffs). They may well have a better take on an industry than incumbent management, who are burdened by other pressures. For example, in the disk drive industry Christensen [1993, p. 579] notes how venture capitalists played a key role in the formation of spinoffs that were founded to commercialize new drives developed but not commercialized by their parents. Christensen claims that incumbents listened too much to their customers, who were initially uninterested in the new drives. Venture capitalists were not comparably unencumbered, perhaps making them better judges of the new drives. Chesbrough and Rosenbloom [2002] tell a similar story about why Xerox's involvement tended to hurt its corporate spinoffs. Xerox had limited experience it could draw upon to advise its spinoffs when they needed to modify their business models. Venture capitalists were apparently better able to provide this kind of advice, and the more they were represented on the spinoff's board then the better the performance of the spinoff.

Thus, the model is not only able to explain the main statistical regularities concerning spinoffs, but it also provides a way to understand a number of other, less prominent observations about spinoffs. Like most models, it also incorporates a number of restrictive assumptions. Some of these can be relaxed without substantively changing the implications of the model. For example, it is not necessary to assume that firms always fail to recognize superior ideas or abilities of employees. As long as the probability of not recognizing such an idea or ability is independent of the characteristics of the firm, all the implications of the model still follow. Other assumptions are more important. It was assumed that potential spinoff founders believe they have superior information or abilities and in fact do. Suppose, however, that they believe their information or abilities is superior but it is not. This corresponds to where the n^{th} individual thinks α is less than one when in fact it equals one. Then it is easy to show that the n^{th} individual would allocate too much weight to his views relative to the optimum and both spinoffs and their parents would be below average performers. To the extent that some spinoffs are founded under these circumstances, this would strengthen the implication of the model that the performance of spinoffs and their parents are positively related. However, it would weaken the prediction that better-performing firms would have higher rates of spinoffs and that spinoffs would be superior performers. This suggests that mechanisms such as the capital markets or the need to form a team of founders may play an important role in disciplining spinoffs and preventing the formation of too many miscalibrated spinoffs.

VI. Discussion

We offered a new theory of spinoffs. It is useful to reflect on how it relates to other theories of spinoffs and on the insights that may be gained from the model regarding agglomerations, technological change, and public policy.

We noted that other theories of spinoffs fall into three groups. One group emphasizes that incumbents generally would be better positioned than spinoffs to develop new ideas because they have complementary assets that typically are not fully utilized. If they cannot protect their intellectual property, however, employees may find it more profitable to exploit discoveries in their own firms, which would be socially wasteful. The model suggests another reason for not reaching the first-best outcome—parents may not recognize the value of the ideas proposed by employees. The experience of spinoffs in the laser industry is instructive. Founders confirmed that patents could be easily invented around, but they also universally signed non-compete covenants that could have been used to hinder their formation. Yet the covenants were not enforced despite the great overlap between the lasers produced by spinoffs and their parents (Sherer [2006]). One explanation is that parents did not hinder the formation of the spinoffs because they were uninterested in their ideas, as stressed in the model. While the first-best outcome would be to have new ideas developed in parent firms if the ideas require complementary assets already possessed (and underutilized) by their parents, this outcome will not be achievable if parents are limited in their abilities to evaluate new ideas.

A second group of theories features how certain ideas may be more profitable to spinoffs than parents. One reason is that firms may have difficulty managing ideas that do not fit their core strategy (Hellman [2002]). Moreover, if they are limited in their capacity to pursue new ideas, ones further from their core strategy may be the least profitable to pursue (Cassiman and Ueda [2006]). Garvin [1983] argues that in fact spinoffs tend to pursue "niche" kinds of ideas that fall outside the core areas of their parents. While this might be because these ideas would not be profitable for their parents to pursue, the model suggests an alternative explanation. It might be expected that the further ideas are from the core of what a firm does, the harder it would be for the firm to evaluate the ideas. So it might be expected that spinoffs would often pursue niche kinds of ideas, but this would not say anything about the profitability of these ideas being developed by their parents.

The last group of theories features employees learning valuable information as a byproduct of their employment that they can profitably exploit in their own firms. Agarwal et al. [2004] suggest that spinoffs often are formed to capitalize on knowledge that their parents create but do not exploit. This would explain why better firms, which presumably create more knowledge, would have a greater rate of spinoffs. But it begs the question of why parents would not exploit all the knowledge they create. The model provides a ready explanation. The founders of spinoffs do in fact exploit the knowledge of others in the firm in forming their strategies. But they also exploit novel ideas that the parent is unable to evaluate. Thus, in the model knowledge is underexploited by the parent firm. Moreover, in the model it is better firms that are more prone to have such unexploited knowledge, but not because they are more fallible than other firms. Rather, all firms have difficulty judging new ideas, but better firms have better employees that are more likely to generate the kinds of ideas that are worthy to pursue but inherently difficult (for all firms) to evaluate.

The model features how spinoffs provide a mechanism to compensate for the limited ability of firms to evaluate new ideas. If spinoffs do not venture from their parents geographically, as has commonly been found (Klepper [2006b], Buenstorf and Klepper [2005]), they will cause the scope of activities in a region to expand. Klepper [2006b] argues that this was the main reason the automobile industry agglomerated historically around Detroit, causing the population of Detroit to grow from approximately 300,000 people in 1900 to over 1.8 million by 1930.

We have already noted that the most prolific parents in the automobile industry were Olds, Cadillac, Ford, and Buick/GM, all of which were located in Detroit, MI or nearby. A few examples will illustrate how spinoffs from these firms expanded the range of automobiles produced in Detroit. Dodge Brothers, which was a spinoff of Ford, is instructive. The Dodge brothers left Ford Motor Company in 1914 when Ford was dominating the industry. They built upon their experience at Ford with the Model T but came out with a sturdier and improved car that sold at a higher price than the Model T. By 1920, the year the Dodge brothers both died, the company achieved the number two position in the industry with sales of 141,000 cars. This does not seem to have had much effect on Ford's sales, which grew from 10,202 cars when the Model T was introduced in 1908 to 501,462 in 1915 and to 1,817,891 at its peak in 1923 (Klepper [2006b]). Similar patterns were played out with many of the other spinoffs and their parents, especially Chevrolet and General Motors. After acquiring Chevrolet, GM applied its complementary assets to Chevrolet to become the number one seller in the industry, all the while increasing the sales of its other models (Klepper [2006b]).

The flip side of this argument is that if entry into an industry, including spinoffs, gets closed off, then an outlet for dissident ideas will be foreclosed. The consequences for technological change will be particularly severe if the industry also experiences a shakeout after entry ceases, which is what occurred in autos, tires, and disk drives (Klepper [2002], Chesbrough [2003b]). A few firms can end up as gatekeepers for the innovative ideas that get pursued, which could be socially harmful if firms are inherently limited in their ability to evaluate new ideas, as featured in the model. This could explain the poor performance in modern times of the auto, tire, and television receiver industries in the United States. All were slow to adopt new innovations when the number of firms dwindled to just a few viable competitors (cf. Klepper [2006c]).

This suggests it would be desirable to protect spinoffs from being suppressed by their prospective parents and possibly even to encourage spinoffs. Firms can use litigation related to trade secrets to prevent or handicap spinoffs. Some firms such as Intel use such practices as a matter of policy (Jackson [1998]). Parents do need to be protected by spinoffs that infringe on their intellectual property, but if lasers are representative, this does not occur very often (Sherer [2006]). Stuart and Sorenson's [2003] findings suggest that spinoffs are more likely in states where the law makes it more difficult to enforce non-compete covenants. Consequently, it might be desirable public policy to enact restrictions generally on the enforcement of non-compete covenants.

Spinoffs could also be actively facilitated. Most new firms are founded by multiple individuals, reflecting the need for a founding team with diverse expertise. Sherer [2006] found that in lasers, nearly all the founding teams knew each other from prior employment at the same firm. High-turnover labor markets such as Silicon Valley presumably foster more of such interactions, making it easier for founding teams to form and thus beneficially promoting spinoffs. In other areas, public policy conceivably could foster the formation of spinoffs by sponsoring interactions across top level managers in different firms.

Spinoffs can confer many social benefits, and they can help explain how agglomerations such as the automobile industry around Detroit emerge. Indeed, Moore and Davis [2004] tell a similar story about how spinoffs in the semiconductor industry drove the development of Silicon Valley and its extraordinarily dynamic economy. Our model provides a way to understand how spinoffs could bring this all about.

Appendix

A. *Proof that* $\partial E\left[v_t \mid \theta\right] / \partial(\theta^2) < 0$, $\partial E\left[v_t \mid \theta\right] / \partial\alpha < 0$, and $\partial E\left[v_t \mid \theta\right] / \partial\omega_n > 0$.

The expected value of the firm conditional on θ is

$$E\left[v_t \mid \theta\right] = A - \int_{-\infty}^{\infty} \left(\theta - \theta_t\right)^2 dF(\theta_t \mid \theta), \tag{A.1}$$

where

$$\begin{aligned} \theta_t &= (1-\omega_n)\theta_{it} + \omega_n \theta_{nt} \\ &= \frac{t\sigma_\theta}{n(t\sigma_\theta + \sigma_\varepsilon)}\left[\left(1 - \frac{\omega_n(1-\alpha)}{1+(n-1)\alpha}\right)\sum_{i=1}^{n-1}\overline{s}_{it} + \left(1 + \frac{\omega_n(n-1)(1-\alpha)}{1+(n-1)\alpha}\right)\overline{s}_{nt}\right]. \end{aligned} \tag{A.2}$$

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

$$\operatorname{var}(\theta_t) = \frac{t\sigma_\theta^2\sigma_\varepsilon}{n^2(t\sigma_\theta + \sigma_\varepsilon)^2}\left[(n-1)\left(1 - \frac{\omega_n(1-\alpha)}{1+(n-1)\alpha}\right)^2 + \alpha\left(1 + \frac{\omega_n(n-1)(1-\alpha)}{1+(n-1)\alpha}\right)^2\right] \tag{A.3}$$

which is strictly increasing in α and strictly decreasing in ω_n. Rewrite (A.1) as

$$E\left[v_t \mid \theta\right] = A - \int_{-\infty}^{\infty} \left((\theta-\mu_t)-(\theta_t-\mu_t)\right)^2 dF(\theta_t \mid \theta)$$

$$= A - (\theta-\mu_t)^2 + 2(\theta-\mu_t)\int_{-\infty}^{\infty}(\theta_t-\mu_t)dF(\theta_t \mid \theta) - \int_{-\infty}^{\infty}(\theta_t-\mu_t)^2 dF(\theta_t \mid \theta)$$

$$= A - \theta^2\left(\frac{\sigma_\varepsilon}{t\sigma_\theta+\sigma_\varepsilon}\right)^2 - \mathrm{var}(\theta_t)\,. \tag{A.4}$$

From (A.3) and (A.4) we therefore have $\partial E\left[v_t \mid \theta\right]/\partial(\theta^2) < 0$, $\partial E\left[v_t \mid \theta\right]/\partial\alpha < 0$, and $\partial E\left[v_t \mid \theta\right]/\partial\omega_n > 0$.

B. *Proof that* $\lim_{T\to\infty} F\left(T \mid \phi_1^*, \phi_2^*\right) < 1$.

Let $F\left(T \mid \phi_1^*, \phi_2^*\right)$ denote the distribution of first passage times for (11). Doob [1949] has shown that $\lim_{T\to\infty} F\left(T \mid \phi_1^*, \phi_2^*\right) = \sum_{j=1}^{\infty}(-1)^{j+1}e^{-2\phi_1^*\phi_2^* j^2}$, which gives the probability that *n* ever forms a spinoff. We can easily show that this probability is strictly less than one. Let $x_n = (-1)^{j+1}\exp\{-2\phi_1^*\phi_2^* j^2\}$ and $s_k = \sum_{j=1}^{k} x_k$. We have $\lim_{k\to\infty}\left|s_k\right| < \sum_{j=1}^{\infty}\exp\{-2\phi_1^*\phi_2^* j^2\}$ $< \sum_{j=1}^{\infty}\exp\{-2\phi_1^*\phi_2^* j\} = 2\left(\exp\{-2\phi_1^*\phi_2^* j\}-1\right)^{-1} < \infty$, 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, $\lim_{T\to\infty} F\left(T \mid \phi_1^*, \phi_2^*\right) \le x_1 = \exp\{-2\phi_1^*\phi_2^*\} < 1$.

C. THEOREM 1 (Choi and Nam [2003, Theorem 7]). *The distribution of first passage times for any* $\phi_1^* > 0$, $\phi_2^* > 0$, *and* $T > 0$ *is*

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

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 $\sqrt{T}x_{5j} = (1+4j)\phi_1^* + \phi_2^* T$.

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