KNOWLEDGE INHERITANCE, VERTICAL INTEGRATION AND ENTRANT SURVIVAL IN THE EARLY U.S. AUTO INDUSTRY

Nicholas Argyres
Olin Business School, Campus Box 1133
Washington University in St. Louis
One Brookings Drive
St. Louis, MO 63130
Phone: 314-935-6391
argyres@wustl.edu

and

Romel Mostafa
Ivey School of Business
University of Western Ontario
1151 Richmond St. N
London, ON N6A 3K7, Canada
TEL: (519) 661-4206
rmostafa@ivey.uwo.ca

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ABSTRACT

The economics and strategy literatures have shown that vertical integration decisions are determined by transaction costs and differential firm capabilities. The sources of differential capabilities, however, are not well understood. This paper studies the impact of new firms' capability endowments on their early vertical decisions, and the implications for their survival chances. We do this by studying employee spinoffs: new firms founded by former employees of incumbents. We find that in the early U.S. auto industry, a spinoff was more likely to vertical integrate a key transaction if its parent firm did, even after controlling for asset specificity. This suggests a mechanism by which spinoffs seek to exploit production knowledge inherited from their parent firms. However, we argue and find evidence that this knowledge inheritance only enhances spinoff survival if it enables the spinoff to establish a defensible strategic position in the market.

INTRODUCTION

While many studies have shown that firms' vertical boundary decisions are determined by transaction costs (for surveys see: Klein & Shelanski 1995; Klein 2005; Macher & Richman 2008) the strategy literature has argued and shown that such choices also depend on buyers' and supplier's relative production capabilities (e.g., Kogut & Zender 1992; Langlois 1992; Argyres 1996; Barney 1999; Leiblein & Miller 2003; Jacobides & Winter 2005; Jacobides & Hitt 2005). However, while it is fairly clear what influences transaction costs (e.g., asset specificity), it is less clear what gives rise to differential firm-level capabilities.

Understanding the sources of firm capabilities and their relationship to firm boundary decisions is important because an early decision to internalize a key activity can influence the performance of that and related activities, and create the foundations for the subsequent development of capabilities and internalization of further activities (Argyres & Zenger 2011). Thus, understanding the impact of firm capabilities on early vertical integration choices provides insights to the eventual formation of superior capabilities (Helfat & Lieberman 2002), which in turn become a basis for competitive advantage (e.g., Penrose 1959; Richardson 1972; Nelson & Winter 1982; Amit & Shoemaker 1993; Madhok 1996; Teece, Pisano & Shuen 2007).

This paper aims to shed light on the relationship between sources of firm capabilities, boundary choices, and firm performance by examining whether a new firm's endowment of capability affects its key early vertical integration decisions, and when these endowment effects are likely to improve firms' survival chances. We study a particular but important source of such endowments; namely, production knowledge that is transmitted from incumbents to their employee spinoffs. Employee spinoffs are new firms established in an industry by former employees of industry incumbents. New firms such as spinoffs are promising for studying the sources of firm capabilities because such firms have not been subject to the kinds of mergers, acquisitions, reorganizations and multiple internal investments over time that complicate the identification of capability sources in established firms (e.g., Karim & Mitchell 2000; Karim 2006).

Recent studies have found that spinoffs constitute a substantial source of entrants into a variety of industries, and are important drivers of the evolution of those industries (for a review, see Klepper 2009). A key finding in the literature is that spinoffs tend to outperform other new entrants. This finding is attributed to the better capabilities that spinoffs develop by exploiting the knowledge that was passed on to them from their parent firms (i.e., the incumbent firms which involuntarily generated them). Thus, an important source of a spinoff's superior capabilities is "knowledge inheritance" from its parent (Agarwal, Echambadi, Franco & Sarkar 2004; Klepper & Sleeper 2005; Chatterji 2009). However, little is known about the role played by vertical boundary choices in this knowledge transfer process, nor about the conditions under which a knowledge inheritance, by influencing spinoffs' early vertical boundary decisions, can affect firm performance. These are the questions that our study addresses.

Our study is set during the early evolution of the U.S. auto industry, when spinoffs played a key role in driving the industry's development, with firms such as Ford, Chevrolet and Lincoln being started by former employees of older auto companies (Klepper 2007). A key decision facing spinoff founders during this period concerned whether to produce engines inhouse or to source them through contracts with independent engine suppliers. This boundary decision was of great importance because the engine was the costliest component of the automobile, and was the key contributor to the car's overall performance and therefore, its value to customers (Bigelow & Argyres 2008).

We find that firms were more likely to integrate engine production at the time of entry if they had a parent firm that also integrated engine production, even after controlling for transaction cost and broader capabilities effects on the integration decision. This suggests that this key vertical boundary decision for spinoffs was significantly influenced by the relevant production knowledge that was transmitted from parent firms. We also find that inherited knowledge relevant to engine production improved survival chances mainly by enabling inheriting spinoffs to better establish strategic positions in the higher value-added market segments that were more defensible in the automobile market of the time. For example, inheriting spinoffs out-survived orphan firms than vertically integrated engine production and managed to establish positions in the more defensible segment.

Our findings make several contributions relative to the literature. For example, while previous research in strategy has emphasized the role of differential firm capabilities in influencing firm boundary decisions, our research suggests that an important source of differential capabilities impacting such decisions is knowledge inheritance from parent firms. The literature on the role of capabilities in vertical integration has largely sidestepped the question of the origin of those capabilities (Jacobides & Winter 2011). In addition, while prior research has linked the knowledge exploited by spinoffs to parental knowledge, our study sheds additional light onto the mechanisms through which knowledge is transferred and exploited in the spinoff process. Moreover, while the literature on spinoffs explains the exemplary performance of spinoffs due to their lineage, we extend this view by showing that knowledge inheritance exploited by vertical integration can lead to superior survival chances by enabling the firm to achieve better strategic positioning. We thus link together the phenomena of knowledge inheritance, vertical integration and strategic positioning to explain firm survival. These three phenomena tend to be treated disparately in the literature, rather than in combination.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Vertical integration. According to transaction cost economics (TCE), firms decide whether to integrate a given transaction based on the level of transaction costs associated with carrying it out through a market-based contract or alliance, as compared with the organizational costs associated with carrying it out internally. Transaction costs are greater when the assets at stake in a transaction have low value if used for any alternate transaction (Williamson 1975, 1985; Klein, Crawford & Alchian 1978). The reason is that transactions featuring such asset specificity are subject to hold-up by an opportunistic partner, whereas internal transactions are much less subject to such opportunism. Transaction costs are magnified if a transaction features asset specificity and is also subject to high uncertainty and is carried out repeatedly (Williamson 1975).

Capabilities views of the firm, on the other hand, have emphasized that firms decide whether or not to integrate a transaction primarily based on the level of capabilities that the firm possesses relative to those possessed by potential suppliers (e.g., Demsetz 1988; Kogut & Zander 1992; Barney 1999; Jacobides & Winter 2005). The notion is that firms differ in their productive capabilities independent of scale, and that if some firms can carry out the same activity, or transaction, at lower cost than others, they will do so. Evidence for the effects of capability differences on vertical boundaries is also prevalent (e.g., Argyres 1996; Poppo & Zenger 1998; Leiblein & Miller 2003; Jacobides & Hitt 2005).

Whereas the sources of transaction costs are fairly clear (lying in the nature of the assets at stake in a transaction) the sources of differential capabilities are less clear. It is thought that firm capabilities develop as a result of a path dependent learning process within firms, as organizational routines and problem-solving approaches become refined over time, often in ways unique to the firm in question (e.g., Nelson & Winter 1982; Langlois 1992; Langlois & Robertson 1989). The most important firm-level capabilities are thought to be "dynamic capabilities": i.e., capabilities associated with making internal adjustments to environmental changes (e.g., Teece, Pisano & Shuen 1997; Eisenhardt & Martin 2000; Winter 2003). However, exactly how and when superior firm capabilities emerge from path dependent learning processes is less well understood. Understanding how such capabilities arise as a result of firms' strategic choices is particularly important for understanding the key drivers of vertical integration, and ultimately of firm financial performance (Argyres 2011).

Some unique firm capabilities have their origins in prior investment decisions by firms. Indeed, at their very formation, and during their early growth, firms make decisions about what kinds of activities to perform in-house, and which to contract for. Such early decisions set the firm on a path of capability development that influences later vertical integration decisions, and ultimately, firm performance. The early investment decisions that lead to superior capability almost by definition involve investment in unique and therefore firm-specific assets. Such investments are likely to have been made internally by the firm itself, rather than by an independent supplier to the firm. Moreover, early investment decisions involving a firm boundary choice (that is, whether to perform an activity in-house or through contract) are likely to have been influenced by transaction cost considerations (Argyres & Zenger 2011). Thus, differential firm capabilities are often rooted in past decisions made on the basis of transaction cost considerations, so that capabilities determinants of boundary choices are intertwined with, and impossible to separate from, the ultimate transaction cost determinants of those choices (Argyres & Zenger 2011).

Early vertical integration decisions may also be influenced by the resources and capabilities with which entrants were initially endowed, prior to making any investment. It has been widely emphasized that firms' pre-entry capabilities play a large role in determining their subsequent success or failure (e.g., Carroll, Bigelow, Seidel & Tsai 1996; Klepper 2002; Helfat & Lieberman 2002). Such endowments may also condition the set of activities that firms can choose to perform upon entry. For example, limited financial resources and access to capital may lead firms to choose less vertical integration than they otherwise would have chosen (e.g., Bigelow & Argyres 2008). On the other hand, pre-entry experience from a related industry may provide a firm with capabilities that lead it to integrate those links in the value chain that benefit from those capabilities (Qian, Agarwal & Hoetker 2011).

In some industries, initial capability endowments are derived from founders' experiences gained though employment by a firm that is *inside*, rather than outside, the industry. Researchers have long emphasized that resources and knowledge are transferred between organizations through personnel migrations (e.g., Stinchcombe 1965; Aldrich & Pfeffer 1976; Almeida & Kogut 1999). More recently, some research has indicated that such transfers occur from incumbents to their employee spinoffs (Agarwal et al. 2004; Klepper & Sleeper 2005; Chatterji 2009). Studies have also indicated that spinoffs have been important in the development of various industries, including semiconductors (Klepper 2009); biotechnology (Stuart & Sorenson 2003); automobiles (Klepper 2007); tires (Buenstorf & Klepper 2009b), medical devices (Chatterji 2009), disk drives (Agarwal, Echambadi, Franco & Sarkar 2004; Franco & Filson

2006; McKendrick, Wade & Jaffee 2009), lasers (Klepper & Sleeper 2005) and high-tech law firms (Phillips 2002).

A number of theories have been proposed to explain why spinoffs occur. According to these theories, the spinoff process is facilitated by limited capacity of incumbents to pursue new ideas (Cassiman & Ueda 2006); limited ability of incumbents to protect their intellectual property (Anton & Yao 1995); incumbents being selective about ideas to pursue (Bhide 2000; Cassiman & Ueda, 2006); and disagreement between employers and their employees, who have better information on the prospect of certain inventions (Klepper & Thompson 2010). All of these theories are consistent with the learning view of spinoffs (cf. Garvin 1983; Klepper 2001; Klepper & Sleeper 2005; Franco & Filson 2006), which assumes that employees learn and apply valuable knowledge while working in established firms and they exploit this knowledge when they establish their own firms in the same industry.

The literature suggests, then, that a firm's current capabilities, together with current transaction costs, influence its vertical integration choices. If the firm is a spinoff, its early capabilities are likely to have been derived from knowledge inherited from a parent firm.[1] Transaction costs, on the other hand, are determined by the asset specificity associated with the transaction in question. Thus, at the time of entry, the spinoff in making its vertical integration decision for a key transaction will take into account the level of asset specificity in that transaction, as well as its capabilities relative to potential suppliers', where its own capabilities are shaped by knowledge inheritance. We define a "key transaction" as a core activity that has a potential for the entrant to establish a defensible strategic position in the industry and thereby

[1] The source of the parent firm's capability in turn likely lies in an integration decision the parent made in the past, driven by transaction costs at the time.

achieve sustained competitive advantage (below, we develop arguments to link vertical integration of a key transaction with performance of entrant and expound on this concept).

Because a spinoff's capabilities are partly derived from its parent, the underlying knowledge relevant to carrying out a key transaction in-house is more likely to have been transmitted through the spinoff process if the parent vertically integrates that transaction. This knowledge inheritance in turn is expected influence the spinoff's own vertical integration decision for that transaction, after accounting for asset specificity in that transaction. In other words, all else equal, spinoffs with parents that vertically integrated a key transaction are more likely to integrate that transaction than entrants that lack the specific knowledge inheritance. These entrants are all other entrants, comprising spinoffs that were generated from parents that did not integrate, and also non-spinoffs (orphan firms) that have no parents from whom they can draw on knowledge. Therefore, spinoffs with the relevant knowledge inheritance would be more likely to integrate the transaction in question than orphans and also more likely to integrate than other spinoffs generated from parents that did not integrate. We therefore seek to test the following hypotheses:

H1a: *A spinoff spawned from a parent that integrates a key transaction is more likely to integrate that transaction than an orphan firm.*

H1b: *A spinoff spawned from a parent that integrates a key transaction is more likely to to integrate that transaction than a spinoff whose parent did not integrate that transaction.*

Note that another implication from the logic above is that orphan firms and spinoffs with parents that did not integrate would not be expected to show any difference in their propensities to vertically integrate a key transaction. This is because both of these entrant types lack the knowledge inheritance-provided capabilities that militate toward vertical integration for a given level of current transaction costs.

Positioning and Survival. As noted above, prior research suggests spinoffs build on the knowledge they inherit from their parents. Beyond that there is significant evidence that spinoffs outperform other new entrants. But how exactly does knowledge inheritance leading to pre-entry capability improve a spinoff's survival chances? **H1a** and **H1b** suggest that capabilities derived from inherited knowledge relevant to a key transaction influence a spinoff's decision to vertically integrate that transaction. Here we suggest that the underlying capabilities that are reflected in vertical integration of a key transaction ultimately improve an entrant's performance to the extent they enable it to establish a defensible strategic position in the industry (Porter1980). In other words, an entrant benefits from such capabilities if those capabilities are crucial in creating and capturing value through greater willingness-to-pay (and price), lower costs, or some combination of the two (e.g., Brandenburger & Stuart 1996).

Consider a capability that is important for sustaining a position of differentiation or cost leadership (Porter 1980). At the time of entry, if the firm lacks this capability -- say because it is an orphan and therefore cannot draw on knowledge from a parent firm – it is unlikely to be able to access the capability from suppliers. This is because by definition, successful differentiation or cost leadership implies that the firm's product or service is unique in some way. Uniqueness in a firm's underlying capabilities is necessary to generate uniqueness in the firm's offering. Unique capabilities in turn imply that the investments made to develop those capabilities must have been at least somewhat idiosyncratic, implying high asset specificity (Ghosh & John 1999; Nickerson, Hamilton & Wada 2001; Argyres & Zenger 2011). Second, unique capabilities are likely to rely in part on proprietary knowledge that is at risk of leakage to rivals should a firm try to access the capabilities through suppliers (e.g., Teece 1986). Transaction cost theory therefore implies that owning such capabilities – rather than contracting for access to them -- will be necessary to create and capture value from it (Williamson 1975; Argyres & Zenger 2011).

The above arguments suggest that defensibility of a strategic position (and therefore its competitive advantage) depends on uniqueness of the underlying capabilities that support that position. Unique capabilities would be reflected in vertical integration of the relevant key transaction which is expected to help sustain the strategic position. We suggest that inherited knowledge relevant to a key transaction contributes to developing such capabilities and making strategic positions defensible. Therefore, we expect that spinoffs that derive capabilities from knowledge inheritance will have an advantage relative to other entrants that do no inherit such knowledge. However, spinoffs can only exploit this advantage to the extent that they leverage such capabilities to help establish a defensible strategic position.[2]

This logic carries a further implication. In particular, we expect that an integrated spinoff with a knowledge inheritance can establish a more defensible strategic position than can a vertically integrated orphan. The reason is that a knowledge inheritance represents the accumulation of longer production experience – and more experience with innovation in production-- compared to a capability that was formed by an orphan without the benefit of such experience. These arguments suggest that spinoffs that inherited production knowledge

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[2] Nickerson et al. (2001) present a framework based on a triplet of choices (see also Ghosh & John 1999). In their framework, a firm jointly chooses its strategic positioning, level of asset specificity for key transactions, and vertical boundary choices for those transactions. In contrast, our analysis focuses on the impact of inherited capabilities, which we assume constitute a knowledge endowment that is given rather than chosen. We suggest that this endowment can influence the vertical integration for a key transaction, holding the level of asset specificity for that transaction constant. This integration decision in turn helps establish the spinoff's strategic position. Over the medium- and –long-term, a firm lacking an inherited capability can in most cases acquire it through the market for corporate control (Argyres & Zenger 2011). In the short-term, however, various kinds of transaction costs and other frictions in the market for corporate control will make acquisition of such capabilities difficult (Langlois 1992; Barney 1999). Short-term considerations are particularly important for new firms facing severe survival pressures in the pre-maturity stages of industry evolution.

important for a key transaction will possess superior capabilities compared to orphans that integrate that transaction, enabling those spinoffs to better defend their strategic positions and survive longer. We therefore hypothesize that:

> **H2**: *Vertical integration of a key transaction will enhance the survival of a new firm to the extent that it contributes to the establishment of a defensible strategic position, and this effect will be stronger for integrated spinoffs that enjoy relevant knowledge inheritance than for integrated orphans.*

In the next section, we explain how we operationalized the notion of "key transaction" and "strategic position" in our context. Our arguments also imply predictions for the survival of other types of entrants. The predicted ranking of various types of new firms in terms of length of organizational life is as follows:

Integrated spinoffs w/ knowledge inheritance > integrated orphans = integrated spinoffs w/o knowledge inheritance > non-integrated orphans = non-integrated spinoffs

AUTO INDUSTRY CONTEXT

Spinoffs played a very important role in the early development of the U.S. auto industry. Some of the most innovative and financially successful firms in the industry were founded by former employees of other auto firms. Examples of spinoff firms include Ford, Chevrolet, Lincoln, Dodge, Duesenberg and Hudson. Moreover, many of these "first-generation" spinoffs generated a second generation of spinoffs, stimulating industry development even further. The frequency and importance of spinoffs are thought to be an important reason for the agglomeration of the U.S. auto industry around Detroit (Klepper 2007).

Vertical integration decisions also loomed large in the early auto industry, as they continue to do today. Many early auto firms were highly disintegrated, operating as assemblers only (Langlois & Robertson 1989). Ford, on the other hand, was famous for its high degree of vertical integration, which Henry Ford believed was necessary to implement his innovative assembly lines and system of interchangeable parts. Scholars have attributed the significant cost advantage at which Ford operated in the 1910s and 1920s in part to its high degree of vertical integration (Nevins with Hill 1954, 1957; Hounshell 1984; Langlois & Robertson 1989). As a variety or design and engineering standards were promulgated throughout the industry in the early 1920's, however, firms found that they were increasingly able to cut costs by vertically de-integrating the production of many components (Katz 1977; Argyres & Bigelow 2010). On the other hand, the one component whose production firms increasingly internalized during this period was the engine (See Table 1).

There appear to be three related reasons why companies increasingly integrated engine production as the industry developed during the 1920's. First, engines, especially larger engines, featured multiple subtle and complex engineering interfaces amongst multiple components including the transmission, ignition, steering system, etc. Coordinating component designs across these interfaces required significant technical communication and therefore involved high human asset specificity (e.g., Masten, Meehan & Snyder 1989; Monteverde 1995). In contrast, other components, such as the rear axle or frame, maintained simpler interfaces with other components (Bigelow & Argyres 2008). Therefore, following transaction cost theory, high human asset specificity calls for vertical integration due to the potential for hold-up (Williamson 1985). Because engines were becoming larger on average during this period, vertical integration of engine production became more common.

A second reason why firms increasingly sought to integrate engine production is that engines, particularly larger ones, were becoming a key differentiating factor for many cars in this period. It was very common for companies to advertise their vehicles based on the quality and performance of their engines (Flammang & Kowalke 1989; Argyres & Bigelow 2010). Driving conditions were still difficult in the 1920's, and many engines were underpowered or unreliable, leading to problems for drivers. Therefore, customers paid significant attention to advertisements in which claims were made about the mountains that cars were able to climb, and distances they were able to travel, similar to the way in which pickup trucks and sport-utility vehicles are advertised today (Interview, Dan Dunn, Blackhawk Museum, Danville, CA; Interview, Leslie Kendall, Petersen Automotive Museum, Los Angeles, CA). With the value of a company's brand name resting heavily on the performance of its engines, many companies – especially those in middle and higher tiers of the market -- were no doubt reluctant to outsource engine production due to the potential consequence of quality-shading or otherwise underperformance by an independent supplier. For larger engines, therefore, integration of the engine transaction was more efficient due to the superior quality monitoring associated with internal organization (Barzel 1982; Williamson 1985).

Finally, it is important to recognize that the period of the 1910's and 1920's was one of fierce competition, and involved a severe industry shakeout (Utterback & Suarez 1995; Carroll et. al 1996; Klepper 2004). In this unforgiving competitive environment, firms in all segments that failed to efficiently organize their transactions – especially their engine transactions – faced reduced survival chances compared to the earlier period in the industry. Firms in all segments that failed to efficiently organize their transactions – especially their engine transactions – faced reduced survival chances compared to the earlier period in the industry (Argyres & Bigelow

2007).[3] An important driver of this increased competition was the introduction of the revolutionary Model T by Ford in 1908. The low-price Model T came to account for 50% of the U.S. market by 1919, in part by leading most of the firms occupying the lowest-price industry segment to exit (Argyres, Bigelow & Nickerson 2011). Firms' survival chances were much higher if they managed to avoid direct competition with Ford during this period by carving out their niches in higher price segments, which in turn called for larger, more specialized engines.

Given the overriding importance of engines to automobile cost and performance in early history of the industry, engine production is the "key transaction" to which we refer in the hypotheses above. We operationalize a strategic position to be a price segment that an entrant participates in the market. Thus, our notion of "establishing a defensible strategic position" in terms of whether a given an entrant was able to avoid competing in the lowest-price segment of the market following the introduction of the Model T. Our theoretical arguments in this context suggest that strategic positions can be made defensible if entrants were able to participate in medium-high price segments which were supported by specialized engines produced in-house. Spinoffs that inherited knowledge on engines are expected to have an advantage because such knowledge is expected to contribute to building specialized engines and enable them to participate in higher price segments than that of Ford.

There are numerous examples in our dataset of spinoffs whose founders and/or early employees were formerly engine designers at a parent firm who left to build different (often larger) engines from which to develop a new car models. These engineers' experiences while

[3] Firms whose car models featured larger engines that were nevertheless outsourced were likely to have suffered production delays due to haggling with engine suppliers, and/or losses in brand reputation due to poor quality engines produced by those suppliers. Moreover, under such cost pressure firms may have been motivated to take control over engine production in order to appropriate returns from investment in engine cost reduction that, if made by suppliers instead, would have been captured partly by those suppliers, and partly by firms' industry rivals (Bigelow & Argyres 2008).

employed with the parent firms, we assume, enhanced their knowledge of engine design nd production, which in turn benefitted the spinoffs they later founded. The spinoffs in our dataset for which we were able to find historical evidence for this kind of knowledge transfer are: Duesenberg, La Fayette[4], Lincoln, Holmes, Parenti, Cleveland, Falcon, Harroun, Gray and Sterling-Knight.[5]

Henry Martyn Leland is an example of a firm founder who transferred key engine knowledge from a former employer to his own start-up (Stoddard 2011). Leland had designed the single-cylinder engine that powered the first Cadillac. He later oversaw the development of the new V-8 engine at Cadillac. In 1917, Leland left Cadillac with his son Wilfred, who was also instrumental in the development of the V- 8 engine, after a dispute with GM head William Durant. Leland wanted Cadillac to convert to production of aviation engines for the WWI war effort, but Durant refused. Leland founded the Lincoln Motor Company, produced aviation engines for the war effort, and after the war began producing luxury cars with newly designed V-8 engines. Lincoln's first car, the Model L, was praised for its precision engineering (Kims & Clark 1989, p. 866).

Other successful firm founders hailed from less successful parents. Fred and Augie Duesenberg had designed engines for Mason of Des Moines, Iowa, a company whose sales were disappointing, and whose ownership was re-organized several times. The company's problems were not attributed to the Duesenberg-designed engines, but to mismanagement of parts procurement (Kimes & Clark 1989, p. 935). The Duesenbergs formed their own company in 1913, building high-performance cars using a similar horizontal-valve rocker-arm engine

[4] La Fayette is a different kind of case from the others on this list. A former chief engineer at Cadillac (not Leland) headed the design of its engines (Stoddard 2011). Its parent is coded as Nash Motors, however, because La Fayette was founded by Charles Nash after he left his former firm. La Fayette in this sense had dual parentage.

[5] Sources include Kimes & Clark (1989), Yates (1994), Hyde (2005, 2009), Stoddard (2011), and various university library and auto enthusiast websites.

technology as they had designed for Mason. Early Duesenberg models were extremely successful on the racing circuit, and the company went on to become an icon of the U.S. auto industry.

DATA AND ESTIMATIONS

The data for our analysis was drawn from a larger database that includes a range of information on auto companies and car components for virtually every firm in the U.S. auto industry during the period 1895-1981. This database was constructed from a variety of historical sources, including Georgano (1982); Baldwin, et al. (1987); Gunnell (19870; Kimes & Clark (1989) and Flammang & Kowalke (1989). Each of these sources represents the culmination of many years of research by historians, journalists, collectors and others. We focused on the early period 1917-1931 in which an industry shakeout occurred, and for which we have information on key components. We combined this data with information gathered by Steven Klepper on every spinoff known to have occurred in the early auto industry (Klepper 2007), as well as with data from Lester-Steele (1960) on automobile component characteristics and other data.

The database identifies 72 entrants in the early U.S. auto industry during this period. Of these, we have sufficient data on 64. While this is a relatively small number of firms, it is close to the population of entrants that are of interest for our study, given our focus on pre-entry capabilities and their effects on vertical integration choices at entry. Therefore, sample size is not a concern in the way that it would be if the population were larger.

To test **H1a** and **H1b**, we conducted probit estimations in which the dependent variable takes the value of 1 if the firm in question vertically integrated the production of the engine for the given car-model-year, and zero otherwise (see Table 3). The explanatory variable of primary interest in this estimation is *Parent Engine In-house*, which takes the value of 1if the firm was a spinoff and its parent produced at least one type of engine in-house at the time of or prior to the spinoff's entry. We also entered *Parent Engine Outsourced*, which takes the value of 1 if the parent firm outsourced engine production. The omitted category consists of orphan firms.[6] **H1a** predicts a positive and significant coefficient estimate for the *Parent Engine In-house* variable, while **H1b** predicts that this coefficient estimate will be significantly larger than that for *Parent Engine Outsourced*.

We included several important control variables in this estimation. First, we included a proxy for the asset specificity associated with the engine in question called *Relative Horsepower*. Interviews with experts at the Blackhawk and Petersen auto museums, well as at the National Automotive Historical Collection in Detroit, indicated that the larger engines during this period tended to require more idiosyncratic investment, or at least were more complex (Bigelow & Argyres 2008). Therefore, we calculated a standardized score of the engine's horsepower (HP) using the mean and standard deviations of HP of car models at the time of a firm's entry. *Relative Horsepower* is coded 1 if the standardized score is equal to or greater than 1, but below 2, and it is coded 2 if standardized score is 2 or above. Any score below one is coded as 0. (We also used the raw standardized scores with lower bound zero for horsepower below the industry mean, and the results, not reported, were similar). We also included a measure of the number of available engine suppliers, *# of Engine Suppliers*, to additionally control for the transaction costs associated with relying on independent suppliers for engine production in the given year (Williamson 1975).

[6] Prior research has found significantly greater survival chances for entrants from a related industry (*de alio* entrants), both in the data studied here, and in data from other industries (e.g., Carroll et al. 1996; Klepper 2002; Argyres & Bigelow 2007). For this study, we included *de alio* entrants in the "orphan" category. Changing the categorization to allow for a separate *de alio* category does not change the results of either the probit or survival estimations.

Firms may vertically integrate the production of a component if they expect to achieve economies of scope across multiple products that use the component. As Riordan and Williamson (1985) show, such economies may exert an independent effect on vertical integration, even if most of the overall effect is likely to be felt through proxies for transaction costs. We therefore included a measure of the number of car models produced by the firm in the given year, *# of Models*. We also included a control to proxy for the transportation costs that might be involved with outsourcing engine production to a supplier. The variable *Michigan* takes on the value of 1 if the firm in question was located in the state of Michigan (relatively close to the engine supplier base), and zero otherwise. In this period, the industry was heavily concentrated around Detroit, Michigan and in the bordering states of Ohio and Indiana. We included measures of *Industry Production* and *GNP* in order to proxy for resource constraints that might have prevented firms from vertically integrating during a given year, or from outsourcing due to supplier weakness.

In the probit estimations, we additionally controlled for the overall production capabilities of the firm by including a variable, *Early Entrant*, that takes the value of one if the firm entered during 1919 or earlier, and zero otherwise. Klepper (1996, 2002) emphasizes the importance of early entry for the development of superior production capabilities in general, including in the auto industry (Klepper 2004). Superior production capabilities in general may be associated with engine integration. We also included two measures of the quality of the production capabilities of the firm's parent, *Parent Market Share* (measured in the year that the spinoff was established) and *Parent Survival* (the number of years that the parent survived). We entered these variables because the literature on spinoffs has repeatedly found that better-performing parents yield better-performing spinoffs. This might suggest that because superior parents generate employees with superior skills, spinoffs from superior parents are more likely to integrate engine production. (The Duesenberg case above is a counter-example.) We entered the parent quality measures first separately and then together because they are highly correlated. A potential concern is that these may be crude measures of parent quality.

To test **H2**, we estimated hazard rate models of exit using the Gompertz specification (see Table 4). The Gompertz specification is appropriate for this data based on non-parametric tests, and for that reason was used in other analyses of exit from the early auto industry (Carroll et al. 1996; Klepper 2004). The explanatory variables of interest for **H2** are interactions between dummy variables for two types of entrants of interest and a dummy variable for strategic position described below.

Spinoff In-house Engine Parent Also carries the value of 1 if the firm in question integrated its engine production and its parent did so also, otherwise its value is zero. *Other Spinoffs* is coded as 1 if the firm was a spinoff but did not produce engines in-house or did produce engines in-house but whose parent did not produce engines in-house. (We did not separate these categories because very few spinoffs vertically integrated engine production if their parent did not). The variable takes a value of zero otherwise. *Orphan Engine In-house* is coded as 1 if the firm was not a spinoff but had in-house engine production around the time of entry, and zero otherwise. The omitted category consists of orphans that outsourced their engine production. The dummy variable for strategic positioning is *Med-High Segment*, measured as 1 if the price of the car model using the engine in question (the highest-priced model if the firm offered multiple models) in a particular year is greater than 1 standard deviation but less than 2 standard deviations from the industry mean (around the time of entry).[7] It is coded 2 if the price is greater than 2 standard deviations from the industry mean. Otherwise, it is coded as zero.

As noted above, the fiercest competition in this period occurred in the lowest-price segment due to the introduction of the revolutionary Model T by Ford in 1908. Competition was certainly stiff in higher price segments as well, but product differentiation and the lack of a dominant firm like Ford in those segments moderated it. Our tests of **H2** aare therefore based on estimating the coefficients on the interaction terms *Spinoff In-house Engine Parent Also X Med-High Segment* and *Orphan In-house Engine X Med-High Segment*. **H2** implies a negative and significant coefficient estimate on the former variable. It also implies that the coefficient estimate on the latter will be smaller in absolute value than that on the former. Our use of these interactions reflects the nature of our data, and does not allow us to conclusively demonstrate that a choice to integrate engine production *enabled* the establishment of a defensible strategic position. However, our data do allow us to examine statistical associations between engine integration, the establishment of a defensible strategic position and enhanced survival (as **H2** hypothesizes). These associations, if significant, would be strongly suggestive of this enablement idea.

The control variables for hazard rate models are similar to those for the probit estimation. Each of these variables could possibly affect firm survival chances in some way. For example, prior firm survival studies, including those on the early auto industry, have found that early entrants enjoy enhanced survival chances (e.g., Dunne, Roberts & Samuelson 1988; Carroll et al. 1996; Klepper 2004).[8]

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[7] Only a few entrants offered more than one model.

[8] Firm size is usually a significant predictor of survival in these studies, but because we were missing this variable for 6 additional firms, we did not include it in the reported regressions. Including firm size does not alter our results significantly.

Importantly, we included our two measures of parent quality in the hazard model (separately) in order to address a potential source of endogeneity. In particular, the effect of engine integration by a spinoff on its hazard rate may partly reflect the overall superiority of its parent, as opposed to the spinoff's engine knowledge inheritance specifically. This concern may be exacerbated if spinoffs were discriminating, such that those from high quality parents were more likely to integrate engines than those from low quality parents. (It was for this reason that we entered the parent quality measures in the probit regressions on vertical integration.) Controlling for parent quality using parent market share and survival in the hazard models helps to address the potential endogeneity. (While ideally one would like to correct for such endogneity using two-stage methods, we are unaware of such methods for hazard rate models.)

In Model 8, we added dummy variables representing whether or not the firm in question integrated production of four different component types besides engines: clutch, frame transmission, and steering. Our aim here was to control for potential interdependencies across components in vertical integration decisions (e.g., Bigelow & Argyres 2008; Novak & Stern 2009). These controls also indicate whether integration other component production was important for survival, or whether the engine was really the key transaction.

RESULTS

Table 2 provides descriptive statistics and inter-correlations for variables in our regressions. The high negative correlation between *Industry Production* and *# of Engine Suppliers* (and *GNP* and *# of Engine Suppliers*) likely reflects the trend toward vertical integration of engines as industry production and GNP grew during the period. Dropping all but one of these latter three variables from the models does not make the remaining variable statistically significant, indicating that multi-collinearity is not causing the lack of significance of these variables.

Table 3 provides the coefficient estimates from the probit estimations of engine vertical integration. Consistent with transaction cost economics, our proxy for asset specificity is positive and significant in all four models. In addition, the positive and significant coefficient estimates on *Parent Engine In-house* in Models 1-4 provides support for **H1a**, since it implies that spinoffs whose parents integrated were significantly more likely to integrate the key transaction (engine) than were orphan firms (the omitted category). The marginal effect based on Model 2 implies that a spinoff whose parent integrated engine production was 47% more likely than an orphan firm to integrate engine production itself. Models 1-4 also provide support for **H1b**, because the absolute value of the difference between the coefficient on *Parent Engine In-house* and that on *Parent Engine Outsourced* is significantly different from zero in all four models (e.g., from Model 2, $\chi^2 = 3.26$; prob. $> \chi^2 = 0.07$).[9] Our theory also led us to expect the non-significant sign on *Orphan In-house Engine*, because both orphans and non-integrated spinoffs (the omitted category) lack a knowledge inheritance that militates toward engine integration.

Table 4 provides the coefficient estimates for the firm survival models. Model 1 shows a negative and significant coefficient estimates on the *Spinoff In-house Engine Parent Also,* indicating that spinoffs with a knowledge inheritance that integrated the key transaction out-survived orphans that did not integrate the transaction (the omitted category).[10] Introduction of the interaction term, *Spinoff In-house Engine Parent Also X Med-High Segment* , in Models 6-8,

[9] We also ran regressions similar to Models 2 and 3, but for components other than engines. The idea was to test our assumption that engine production indeed constituted a "key transaction", for which integration decisions were likely to be different than for other components. We found that spinoffs with parents that integrated a given non-engine component were *not* more likely to integrate production of that component. The non-engine components for which we have sufficient data are: ignition, transmission, steering, clutch, and frame.

[10] According to this model, other spinoffs and orphans that integrated the transaction were no more likely to survive than orphans that did not integrate the transaction.

however, renders *Spinoff In-house Engine Parent Also* non-significant. Thus, there is suggestive evidence that knowledge inheritance contributed to the survival of those spinoffs by enabling them to establish defensible strategic positions away from Ford. The negative and significant sign on *Spinoff In-house Engine Parent Also X Med-High Segment* implies that spinoffs with the relevant knowledge inheritance that vertically integrated engines and positioned themselves in the mid and high price segments out-survived other entrants, consistent with **H2**.

The negative and significant sign on *Orphan In-house Engine X Med-High Segment* indicates that orphans that integrated engine production and used it to establish a defensible strategic position out-survived other entrants, with the exception of integrated spinoffs that inherited the relevant knowledge and served mid and high price markets.. This is shown by the significantly smaller coefficient estimate on *Spinoff In-house Engine Parent Also X Med-High Segment* than that on *Orphan In-house Engine X Med-High Segment* (from Model 6, $\chi^2 = 4.13$; prob. $> \chi^2 = 0.04$). This result again highlights the benefits of knowledge inheritance when applied to a establish defensible strategic position, and provides evidence in support of **H2**. Finally, Model 8 shows that our survival effects are robust to the inclusion of dummy variables (none of which are significant) for the vertical integration of other components besides engines.[11]

[11] In unreported regressions, we also entered a variable into the survival models labeled *Transaction Misaligned*, which takes the value 1 if the firm produces the engine in-house and its horsepower is less than 1 standard deviation from the industry mean (around the time of entry), or is greater than 1 standard deviation from the industry mean (around the time of entry) and the firm outsources the engine (Argyres & Bigelow 2007). It is coded as 0 otherwise. Because larger engines tend to feature more asset specificity, efficient firms would be expected to internalize their production, while outsourcing the production of smaller engines lacking in asset specificity. Transaction cost efficiency would be expected to affect the firm's survival chances. The coefficient estimate on *Transaction Misaligned* was not significant in any regression, and none of our main results change with its inclusion. We excluded it from the reported regressions because given overwhelming competition from the Ford Model T in the low-price segment, we would not necessarily expect that even aligned firms in the lowest-priced segment would out-survive misaligned firms in the medium or high segments.

DISCUSSION AND CONCLUSION

Our results can be seen as contributing to the literature on the determinants of firm boundaries, as well as to the literature on spinoffs. With regard to vertical integration, it has long been argued in the strategy literature that through path dependent learning processes, firms develop capabilities that other firms lack, and that this specialization determines firm boundaries (e.g., Demsetz 1988; Kogut & Zander 1992; Jacobides & Winter 2005). However, in this literature the question of the origin of those learning processes – that is, what determines the directions they take – is generally not addressed (e.g., Jacobides & Winter, forthcoming). Our results here suggest that knowledge inheritance is an important source of superior capabilities that help determine early boundary choices. Moreover, our results suggest that knowledge inheritance, and the integration choices it stimulates, are valuable in that they contribute measurably to firm survival. More specifically, we show that this survival effect occurs through the choice of strategic positioning. Whereas the link between boundary choices and strategic positioning has been drawn in the literature (Ghosh & John 1999; Nickerson et al. 2001; Argyres & Bigelow 2010), our results highlight the link between these two choices and knowledge inheritance by spinoffs.

The literature on spinoffs has generally not addressed the role of firm boundary decisions. Our results suggest that spinoffs may exploit their knowledge inheritance by vertically integrating early on into key activities that their parents also integrated. In that sense, our results point to an organizational mechanism – an organizational choice – that is made in order for a spinoff to take full advantage of its knowledge inheritance. This integration choice involves a significant resource commitment that is not easily reversible, that is therefore strategic. It therefore implies that some directions of spinoff development will be foreclosed. Moreover, the spinoff literature has not delved very far into the implications of knowledge inheritance for the firm's strategic positioning. Our results suggest the knowledge inheritance can have its greatest performance impact through the kind of strategic positioning it can enable the firm to establish.

Future research should continue to investigate the role of early firm boundary choices in the exploitation of knowledge inheritance by spinoffs. For example, one open question concerns when firms can exploit informal relationships with employees of their former firms, or alliances with third parties, to exploit their knowledge inheritance, and when vertical integration is necessary. The literature on the "knowledge boundaries" of firms, as distinct from the "organizational boundaries" of firms, is relevant here (e.g., Brusoni & Prencipe 2001; Kapoor & Adner 2011).

Another question for future research regards the type of pre-entry capabilities that may best enhance firm performance, perhaps through enabling superior positioning. In this paper, we have focused on production capabilities for a key component of a complex product. In other industries, however, other kinds of capabilities may be more important. For example, in some industries contract design capabilities or supplier management capabilities may be able to substitute for full integration of production (e.g., Mayer & Solomon 2006; Argyres & Mayer 2007). Are these kinds of capabilities inherited to advantage by spin-offs in other industries, such as computers, software, or aerospace, for example? This is but one of many directions to pursue in the important study of pre-entry capabilities, spinoffs, and early integration decisions.

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Table 1: In-house Production of Key Components for Auto Models (1917-1931)

Year	# of Models	% of Models with In-house Production:				
		Engine	Transmission	Clutch	Steering	Frame
1917	182	47.46%	NA	NA	NA	NA
1918	173	50.58%	NA	40.99%	NA	NA
1919	122	53.72%	47.90%	42.86%	NA	NA
1920	122	52.88%	40.57%	35.58%	25.24%	20.83%
1921	158	50.96%	35.51%	27.86%	23.31%	13.49%
1922	172	56.36%	39.39%	31.21%	20.75%	17.95%
1923	142	60.00%	40.77%	33.08%	25.58%	16.80%
1924	97	64.58%	46.81%	41.05%	39.77%	19.00%
1925	92	66.67%	48.57%	50.00%	23.44%	17.46%
1926	85	69.41%	53.85%	48.10%	30.38%	20.75%
1927	94	70.97%	55.06%	32.22%	21.74%	17.39%
1928	92	70.93%	55.13%	21.79%	20.99%	16.13%
1929	95	78.82%	55.00%	18.29%	12.99%	26.15%
1930	102	82.98%	47.19%	15.91%	13.75%	18.75%
1931	89	80.68%	53.49%	22.09%	9.46%	25.71%