Learning to Scale or Scaling to Learn? An Empirical Exploration of Production Scaling in the Early American Automobile Industry

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Abstract

This paper makes a context-embedded contribution to the strategic management literature by identifying a specific pre-entry capability that mattered, and by demonstrating that, at least in one case, process innovations are critical from a very early industry stage. This study explores the challenges firms faced while attempting to scale manufacturing during the early American automobile industry (1895-1918). I argue that firms with founding team members who had prior operational experience in a factory that depended upon knowledge of metalworking were able to overcome production bottlenecks and thereby achieve scale. I use multivariate statistics to demonstrate that the founder's metal factory experience was correlated with both the firm's survival and its ability to increase production capacity. I demonstrate the practical use of historical methods by using them to uncover qualitative evidence of causality. Consequently, this study illustrates that extensive exploration of an industrial context reveals unique insights that (a) can only be generated from such an exploration, and (b) reveal the limits of general theories of strategy that do not take advantage of deep exploration of context.

1. Introduction

This study suggests that the founding team's prior operational experience in a factory that manufactured metal products was critical for firm performance during the early stages of the American automobile industry (1895-1918). An in-depth exploration of the context revealed that knowledge of metalworking mattered because it enabled firms to manage the particularly difficult problem of production scaling. Due to similarities between the two manufacturing processes, metal factory experience provided founders with the capabilities needed to overcome production bottlenecks at automobile factories. This experience allowed the firms to gain production efficiencies through skilled factory tooling and streamlined production processes. I demonstrate statistically that firms that had founding-team metal-factory experience, on average, survived longer and increased their production capacity annually. I use historical narratives to discover the existence of the phenomenon, multivariate statistics to subsequently verify that it is indeed relevant to the broader population, and finally, records from the industry archives to triangulate the underlying mechanism. Thus, my findings suggest that bottlenecks to growth, if they do indeed exist, may be context specific and that the capabilities needed to overcome those bottlenecks may also be context specific.

I make the following contributions to the literature: (1) I contribute to the pre-entry experience literature by identifying 'knowledge about how to scale' both as a distinct capability that firms inherit, and as a necessary component of successful entrepreneurial teams in the early automobile industry (Eisenhardt and Schoonhoven, 1990; Klepper and Simons, 2000; Delmar and Shane, 2006; Beckman et al. 2007; Ganco and Agarwal, 2009; Klotz *et al.*, 2014). My finding also suggests that the value of any specific pre-entry experience is context specific because certain inherited capabilities are more useful than others in certain contexts. (2) I contribute to the product life cycle literature by proposing that, in contrast to previous predictions, process innovations may be critical from a very early stage of the industry (Suarez and Utterback, 1995; Murmann and Frenken, 2006; Klepper, 1996; Cohen and

Klepper, 1996). Product life cycle literature suggests that firm success depends initially on product innovation and subsequently on process innovation. However, my findings suggest that process innovations influence the design and viability of product innovations from a very early industry stage. Similarly, product life cycle literature also suggests that a firm's market share determines its R&D investments in process technologies. However, my findings suggest that process innovations are critical to gaining market share from a very early stage of the industry.

This is an abductive study that utilizes the historical explanation to initially generate the likely explanations, and subsequently to determine the loveliest explanation from among them. To justify scaling capability as the loveliest explanation, I use the tools offered by the historical explanation to uncover the complex nature of the scaling problem, the specific functional experience needed to overcome the posed challenge, and the range of actions the experience enabled the firm to undertake. By situating actors in their context and tracing the decision-making processes inside the firms, I use archival records to identify the manufacturing challenges firms faced, the specific skills that were inherited from a metal factory, why metal factory experience enabled production capability in the automobile industry, and the mechanisms through which metal factory experience translated to production capabilities. Thus, I demonstrate the unique insights that strategic management can gain through the use of historical explanation in an abductive study.

I proceed as follows: I describe the literature's view on the challenges that firms face while attempting to scale in section 2. I add specificity to the discussion in section 3 by describing the challenges that firms in the early automobile industry had to overcome while trying to scale production. In section 4 I describe why metal factory experience was relevant to the early industry stage auto firms. I describe the data used for multivariate analysis in section 5, present the statistical findings in section 6, and consider alternate explanations in section 7. In section 8 the implications of these findings for the pre-entry capabilities and product lifecycle literature are discussed. In section 9, I describe the critical role contextual richness plays in revealing the insights presented in the paper and propose future directions. In section 10 I discuss the findings and in section 11, conclude.

2. Scaling

The antecedents and consequences of scaling have received limited attention from management scholars. Scaling refers to the process through which firms modify their existing routines to synchronize their internal organization of work with their escalated production goals (Nelson and Winter, 1982; De Santola and Gulati, 2017). While a variety of factors such as design and engineering excellence, marketing capabilities, or financial management skills could explain the observed heterogeneity of performance in the early automobile industry, contemporaneous industry records including books, letters, company records, newspaper articles, and trade magazines consistently reveal scaling as a critical and challenging problem. I focus on the specific challenges associated with scaling, the capabilities needed to overcome these impediments, and the resulting performance advantage.

Firms create competitive advantage by achieving production scale economies (Klepper, 1996). Scale allows firms to generate efficiencies through the effective utilization of equipment, employee specialization, experiential learning, quicker payback on investment, and reduction of overhead costs per unit (Dobrev and Carroll, 2003). It permits greater access to complementary technologies and resources such as finance and marketing capabilities (Cohen, 1995; Dussauge et al., 2004). It permits greater and more diverse experimentation to facilitate more complex problem solving (Macher and Boerner, 2006). Scale also creates a barrier to competition. As noted by Knudsen, Levinthal, and Winter (2014; 1581), "even in the absence of economies of scale, an established firm operating at significant scale benefits from an advantage over potential and actual entrants ... [because, scale] shields off a small set of firms from the competitive force of continuing entry, even when new firms enter with a potentially superior cost value, or business model." However, the resource-based view suggests that scale is a firm-specific asset with heterogeneous slopes in the size-efficiency relationship rather than a shared asset that acts as a barrier to entry to protect all incumbents. (Madok, 1999).

However, scaling is a challenging process. Scaling requires significant changes to the firm's strategic commitment such that the ineffectiveness of these changes will prove costly for the firm. Scaling requires an expanded scope of activities. Merely engaging on the same set of activities, but with more personnel, limits the firm’s scaling capacity. Rather than replicating or extending an existing set of routines, scaling requires disruptive changes that result in the development of new routines and removal of existing routines (Nelson and Winter, 1982: 119; Mishina et al., 2004). Scaling requires firms to make the tradeoff between duplicating previously successful template versus encouraging local variation, better ways of thinking, experimentation, and customization (Sutton and Rao, 2014). Firms need to modify their internal organizational design by transitioning from an informal/fluid structure to one with clearly formalized functional roles that allow firms to divide complex tasks and manage the complexities and interdependencies of scaling (DeSantola and Gulati, 2017).

Scaling imposes significant adjustment frictions on the firm which makes it difficult for them to engage in the restructuring that is needed to meet the demand or productivity shocks (Pozzi and Schivardi, 2016). Firms often find it difficult to maintain operational efficiency while developing relevant knowledge in the new capacity, resulting in a transition period with heightened costs and efficiency losses (Winter and Szulanski, 2001; Knudsen et al., 2014). While scaling, firms often face adjustment costs arising from "error-prone transmission, or replication, of firm-specific knowledge, amplified by organizational interdependencies and organizational diseconomies of scale adjustment (Knudsen et al., 2014: 1571)." Moreover, the capabilities that make a firm successful may not be scale-free, i.e., the value of the capabilities may be reduced due to the magnitude of firm operations over which they are applied (Levinthal and Wu, 2010). There are also limits to how much firms can scale within a specific period (Penrose, 1959) and the returns to scale need not be continually increasing.

3. Scaling in the early American automobile industry: 1895-1918

The automobile industry in the United States was born in 1895 and faced a turbulent early phase till the emergence of the all steel closed body dominant design in 1923 (For a brief history and industry patterns see Klepper, 2007). The rapid growth of the auto industry mirrored the economic realities of the time. During this period the US population almost doubled from 63.5 million in 1890 to 107 million in 1920, and the US national income almost tripled from 23 billion on 1890 to 65 billion in 1917 (Friday 1918; US Census, 1960). The rapid development of a vast domestic market that had an ever-increasing appetite for improving living standards implied that manufacturers of the latest attractive technological advancements like the automobile could scale, but had to do so quickly.

The organizational factors which affected scaling were critical from the early stages of the automobile industry.[1] Unlike the popular belief that scaling became indispensable only after the emergence of Ford's moving assembly line in 1914 and the subsequent production success of the Model T, historical records suggest that scaling was critical from the onset of this industry. Olds Motor Works captured the market through its mass-produced Curvedash as early as 1901 (Flink, 1990). Historian George May noted that even "by 1903, automobile concerns on both sides of the Atlantic had been faced with the necessity of altering and streamlining their manufacturing techniques in order to achieve large-scale production (1975: 137)."

Prominent Detroit banker Eugene Lewis, writing shortly after World War II, observed that the "making of cars and component units were all new with few precedents to follow (1947: 189)." Scale production of the automobile was perhaps the most challenging endeavor undertaken by the industrial society at the time. Previously mass-produced technologies, the Springfield Armoury Musket

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[1] I gathered information about the industry from the archives housed at the leading American automotive history collections such as the Benson Ford Research Centre, the National Automotive History Collection at the Detroit Public Library, the Western Reserve Historical Society, and the Bentley Library. I used newspapers, letters, gazette publications, phone directories, firm records, automotive histories, autobiographies, social directories, and trade magazines to explore the context.

with ~45 parts (Woodbury, 1960) and the Singer Sewing Machine with ~300 parts (Brandon, 1977), were significantly simpler products than the automobile with ~5000 parts (McCalley, 1994).[2] Moreover, automobile manufacturing required a fundamental shift in the attitudes of the individuals. As noted by the president of the Newark Gear cutting Machine co., "[i]n the general industrial field, machinery is designed relatively heavy—up to the point of clumsiness. Considering the automobile as a machine, it is designed relatively light—down to the breaking point—and yet is surprisingly efficient and lasting. (Eberhardt, 1921)."

From a very early stage, technical and design innovation was a necessary but not sufficient condition for firm success because they could be easily imitated, licensed or purchased (Klepper and Simons, 1997). Production scaling gave firms in the automobile industry "an advantage in R&D because of the larger output over which they can apply the results … (with the advantage) particularly pronounced for process relative to product R&D (Cohen and Klepper, 1996: 241)." From a demand perspective, efficient production processes gave consumers confidence in the quality of the firm. In her study of early automobile advertising, Pamela Laird notes that to reassure buyers and build confidence, automobile manufacturers, especially middle-class automobile manufacturers, included facts and figures about how quantity production reduced costs (Laird, 1996). Manufacturing was so integral to the identities of firms that they even advertised about their production prowess. For example, Chalmers Motor Car Co., in 1912 claimed, "We build our motors, transmissions, axles, self-starter, steering gear, and other im-portant parts. We cut our own gears; heat- treat our steels. We even have our own foundry… No motor car factory is more completely equipped with new machinery (Chalmers, 1912)."

Unpredictability associated with unspecified customer preferences made scaling particularly challenging in the early automobile industry. This uncertainty often prevented firms from making

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[2] Refers to the number of parts in Ford Model T, often considered to be one of the simplest vehicles from the era.

either long-term commitments toward any particular strategic direction or product specific investments during the early stages of this industry. When scaling needs did become evident, firms needed to scale quickly to satisfy the demand. During this stage, entrepreneurs often faced with what Gans et al. (2016), have called the paradox of entrepreneurship in their theory of entrepreneurial strategy. Entrepreneurs had N versions of the product that appeared equally viable. However, whether they can scale a version or whether the scaled version of a product would be successful was uncertain. To overcome this uncertainty, they had to experiment and make strategic commitments towards scaling each version. However, making the strategic commitment towards one version often precluded them from pursuing others due to their limited resources.

Scaling was an iterative process rather than a one-time commitment. Firms needed to stage and efficiently manage their scaling to match predicted demand while ensuring that resources are available to make further updates to the strategy. Since entrepreneurs often overestimated the potential of their ideas (Cassar, 2010), they engaged in over investment rather than staging their scaling process. As noted by Benjamin Briscoe in 1908, firms had to "risk ploughing most of its profits back into improved plant and equipment...and manufacturing gamblers 'plunged' unduly large amounts of capital in light of existing technological uncertainties (Flink, 1970:309)." When early-stage manufacturing firms failed to manage the scaling process efficiently, it resulted in excess capacity, surplus raw materials, and costly long-term fixed contracts. How much resources to spend on building capacity at each stage, and its timing, were complex decisions. Moreover, innovations create technical imbalances between interdependent components, machines, and processes (Rosenberg, 1969). Due to the complexity of the automobile technology and its manufacturing process, resolution of these imbalances required sequencing through multiple iterations.

Firms that successfully scaled had to make substantial organizational architecture changes and orient their entire organization towards building and selling vehicles to large populations. In such firms, top management teams, whose attention has been suggested to have implications for firm actions (Cho and Hambrick, 2006), paid careful attention to the scaling capabilities. For example, surviving meeting minutes from Studebaker's 1915 committee meetings indicate that the management team members "were consciously thinking about productivity improvements in their auto plants, [such as] implementing progressive assembly and otherwise minimizing employees' excuses for wandering around the plant, attempting to plan plant workloads farther in advance, and introducing conveyor belts (Raff,1991:727)." The automobile does not merely present a design problem, but also a manufacturing problem. As noted by early automobile industry pioneer Walter Flanders, "[t]he engineering problem thus becomes one of operation sequence, support for the work, tool design, and — in some cases—design of the work itself (1921: 532)." Early manufacturers simultaneously engaged in process innovation and product innovation because efficient designs were essential to high-quality manufacturing. As noted in the Mechanical Engineering journal, "the difficulty of maintaining accuracy increases in geometric ratio with each added accurate dimension on the same piece (Chester, 1921)." For example, the article continues to state that, the 'percent estimated increase in the ratio of cost per operation' was expected to rise from 30% for 2 dimensions to 500% for 6 dimensions on one piece (Chester, 1921).

4. Significance of pre-entry metal factory experience

Transitioning from prototype construction to scale production of the automobile required an intimate understanding of how a factory operated. Specifically, it required an in-depth understanding of iron and copper manufacturing, knowledge about the use of precision tools, and the management of challenges associated with a large workforce. While the automotive technology was new, the processes used to manufacture the technology was initially an extension of what other metal-use heavy industries were using. For workers, "the shift from carriage or machine shops to auto shops involved little noticeable changes (Peterson, 1987: 105).” Founding team members who were involved in the daily factory operations of mining firms, foundries, tool and die makers, manufacturers of boats, railway carriages, engines, firearms, sewing-machines, roller skates, kerosene lamps, machine tools such as lathes and drill presses, phonographs, bicycles and other metal consumables gained unique production management knowledge that were valuable in the early automobile industry.

Rosenberg’s (1963) theory of technological convergence, suggests that in the early 1900’s metalworking employed similar skills, techniques, and facilities for production of a wide range of products.[3] Due to this technological convergence, solutions to technological problems developed in other industries where metalworking skills mattered, could be rapidly transmitted into the automobile industry. On the manufacturing of automobiles, Rosenberg notes,

> "The problems of large-scale automobile production involved the extension to a new product of skills and machines not fundamentally different from those which had already been developed for such products as bicycles and sewing machines. Underlying the discontinuity of product innovation, then, were significant continuities with respect to productive processes. The transition to automobile production for the American economy after 1900 was therefore relatively easy, because the basic skills and knowledge required to produce the automobile did not themselves have to be ‘produced’ but merely transferred from existing uses to new ones (1963: 437).”

Historians note that the most important factors that contributed to mass production were advances in the production of metals, development of machine tools, usage of precision instruments, and efficient methods of generating power (Williamson, 1967: 679). Metal factory employment provided founders experience with all these aspects that we so critical to the scaling of manufacturing. Thus, I suggest that metal factory employment serves as a proxy to measure the tacit manufacturing capabilities that early industry stage automobile firms needed to scale.

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[3] Describing technological convergence Rosenberg (1963) states, “[P]rocesses and problems became common to the production of a wide range of disparate commodities that industries which were apparently unrelated from the point of view of the nature and uses of the final product became very closely related (technologically convergent) on a technological basis-for example, firearms, sewing machines, and bicycles. (:423)”

Founders with metal factory experience were better equipped to manage the complex task of making an automobile due to the similarities between automobile plants and metal product manufacturing. Much like other metal factories, auto manufacturing in the early stages had four basic steps: foundry work, machining, body making, and final assembly (Rubenstein, 2001; 121). Foundry workers, using their expertise in the preparation and wielding of molten metal, produced the castings designed by the engineering staff. These castings were then used to fabricate the individual parts. Machinists used metal-cutting tools to grind, drill, and buff rough castings and forgings into precision parts. Different parts were subsequently assembled into components such as an engine. Eventually, the various parts and components were assembled to produce the motor vehicle (Meyer, 1981; 11). These steps used a variety of tools such as milling machines, lathes, screw machines, surface grinders, drill presses, boring machines, spindle drills, horizontal millers tooth cutters, metal sheet presses, soldering irons, gas furnace and pneumatic hammers that were similar to metal product manufacturing.

Substantial re-design of models, which, as suggested by Pillai et al., (2018), happened annually from a very early stage, imposed expensive re-tooling requirements on the firms. The pace of technological change was so fast in the industry that "the rapid advance in engineering, design and mechanics rendered models a year old obsolete (Doolittle, 1916: 416)." As noted by industry observers at the time, "standard [manufacturing] practice predicates [the need for] machine tools, jigs, dies and templates to carry out manufacturing and a minor change or two in specifications wrecks the whole idea (Doolittle, 1916: 228)." For example, in 1911, General Motors wanted to adopt "a bevel- gear type differential of a new design which would replace the gear company's goods in Buick, Cadillac, Olds, Oakland, and probably other cars as well. To produce the new gear meant retooling at an expense of at least a half-million dollars (Pound, 1934: 485)." Similarly, before launching their new car in 1914, The Dodge Brothers Company had to spend half a million dollars retooling their factory

(Hyde, 1996). Thus, the factory transitions resulting from the model changes warranted expertise that was predominantly gained through re-tooling experience from metal factories.

Metal factory experience gave founders knowledge about operational challenges associated with scaling and how to overcome them. It allowed them to gain efficiencies through improved processes and tools. For example, Walter Flanders, who had previously worked for multiple metal tool manufacturing factories (Glasscock, 1937; 118), was able to increase the production at the Ford factory in 1906 from twenty to one hundred and fifty cars a day merely by rearranging the existing equipment. Through improved tools designed by their manager who had previous tool-and-die experience, Cadillac was able to reduce the time required for a process by one-tenth in 1905 (*Detroit News*, June 17, 1923), and Ford was able to reduce the amount of time it took to make a fly-wheel from 18 minutes to 1 minute (McNeill, 2002). Edward Budd at Hupmobile, who had previously worked for Symara Iron Works, was able to reduce the time it took to paint vehicles from weeks to just one day (Nieuwenhuis and Wells, 2007). He achieved this by replacing flammable materials with newly designed metal components and subsequently baking on the enamel and various coatings of paint and varnish (Palmer, 1913). The adoption of Vanadium Steel after a two-year development process, which provided three times the tensile strength at much-reduced weights, was crucial to designing and manufacturing durable vehicles at a higher rate (Ford, 1927). To improve efficiency through improved accuracy, rather than guessing temperatures from the color of the metal surface, firms with metal factory expertise introduced pyrometers to give precise readings of treating temperatures (Gartman, 1986: 64). Thus, metal factory experience allowed firms to scale production by engaging in the advanced metallurgy needed to design new types of ingredients that reduced processing times, and by engaging in re-tooling /process improvements.

Metal factory experience of founders provided firms critical access to routines. While scaling requires modification of existing routines, in early-stage industries where there may be a limited number of routines under existence, which routines to follow is often unclear. Even though routines from other industries could be imported to the auto industry, its fit and its ability to contribute towards scaling were unclear in the absence of functional expertise that metal factory experience provided. Since scaling required management of growing geographical footprint, a growing number of employees/consumers/investors, physical assets, an increased amount of financial transactions etc., early-stage firms struggled when effective routines were absent. Often, only when they attempted to scale did many firms realize that transitioning from *batch* production, to *scale* production, at the brisk rate demanded by the industry at the time was not a trivial process.

Examining the type of jobs that happened inside the automobile factory gives an indication of the significance of metal factory experience. For example, towards the end of the observation period, in 1917, a "count of occupations and trades at the Ford Motor Co. found machine hands to be by far the largest groups, comprising 32% of those employed. The next single largest category, about 10%, comprises assemblers (Peterson, 1987: 37)." Considering that towards the end of the observation period the automobile firms were complex organizations with a variety of different task requirements, one may assume that the percentage of machine labor within each firm was even higher during the earlier phases of the industry.

4.1 Tools

One of the most critical knowledge that metal factory experience provided founders is that of machine tools that were indispensable to manufacturing. As noted by the Society of Mechanical Engineers, since automobile manufacturing required continuous production, "it demands and employs every last possibility in cutting qualities of steel, power and accuracy in machines; and particularly in skill in the design of fixtures, tool outfits, and methods of machining (Flanders, 1921: 532)." The auto industry did not merely restrict itself to the use of existing tools; rather it experimented and was even the source of major innovations in the machine tool industry. For example, the President of Toledo Machine Shop Company noted that, "[t]he development of power presses, together with that of dies and special tools, has been so marked in the last twelve years, principally because of the demand for intricate stampings for the automobile trade, that it is believed a far greater advance has been made than at any other period in the history of the business (Hinde, 1921: 530)." Between 1903 and 1912, the automobile industry made a series of innovations in the machine tools it used such as the introduction of jigs and fixtures, compound machines, revolving fixtures, ganging of work, semi-automatic tools and finally, automatic tools (Gartman, 1933: 67). Relevant knowledge about the design and operation that metal factory experience provided was a necessary ingredient for firms to keep pace with such brisk changes.

Grinding tools provide an illustrative example of the significance of tools in the industry and the need for metal factory experience to effectively use them. Grinding tools removes unwanted metallic extensions to the thousandths of inches. Unlike other single-point (e.g., lathe, boring machine) or double-point (e.g., drill press) tools, the grinding machine used thousands of points simultaneously and continuously to smoothen surfaces and attain precision while making parts. It was particularly useful in automobile construction because the alloys that auto industry used to produce strong, lightweight parts "presented difficult problems if machined before heat treatment and insoluble difficulties when hardened, unless techniques of grinding were employed (Woodbury, 1959; 121)."

Though this tool was incredibly useful, only the firms with prior metal factory experience recognized the need and effectiveness of this tool. As noted by the Scientific American, "[g]rinding is the most accurate operation in machining metal. Accuracy is economy - though not all makers seem to appreciate that fact. (January 16, 1909: 55)." Historians note that,

> "The cylinders of few moderate-priced cars are not finished by grinding, boring and reaming only being employed. Bored and reamed cylinders are not true as the pistons and rings, when assembled in the cylinders bear on minute metal ridges only. Approximately one- half the bearing surface cannot be utilized until 0.002 to 0.005-inch of the surface has been worn away and the space thus left between the piston rings and the cylinder walls permits the passage of

> gas and oil. Such cylinder blocks resulted in engine trouble after it has been used for a few months (Jacobs, 1922: 198)."

Firms with prior metal factory experience recognized the benefits offered by this tool and enabled efficient manufacturing of a variety of parts such as the following: (1) The construction of crankshaft, a critical component of the engine that converts the linear up and down motion of the pistons to rotational movement useful for wheel propulsion, required over five hours of processing (Colvin and Stanley, 1908). Usage grinding tools explicitly designed for crankshafts, the E.R. Thomas Motor Car Co. who had prior experience using grinding machines in bicycle manufacturing, reduced the processing time to fifteen minutes in 1905 - a practice eventually adopted by the entire industry (Woodbury, 1959). (2) Camshaft, a critical component of the engine that controls air and fuel inlet valves into the combustion chamber at specific times, were made using a long, time-consuming, and inaccurate method in which each component was manufactured separately. Firms that adopted grinding machines were able to manufacture the camshafts more precisely from a single piece of hardened alloy. (3) Pistons rubbing against inaccurate engine cylinders resulted in metal fragments entering the lubrication system. However, it was of the utmost importance that the cylinder bores stood square with the bottom of the cylinder block (Jacobs, 1922). Grinding machines smoothened these surfaces accurately that permitted better engine operation. Thus, the efficient use of tools not only allowed higher quality production that translated to demand, they also reduced the time to produce and thereby enabled scaling.

5. Data

My sample consists of American firms that commercially sold automobiles from 1895-1918.[4] The data collected resides inpaper archives at the leading automotive history collections such as the Benson

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[4] Following the U.S. entry into World War I, the War Industries Board put resource consumption restrictions on the industry starting 1919 (Motor Travel, 1918). Due to fundamental changes that happened in the industry because of these restrictions, such as cancellation of auto shows and firms delaying the release of new models, the observation period ends at 1918.

Ford Research Centre, the National Automotive History Museum, the Western Reserve Historical Society, and the Bentley Library. Due to the magnitude of the data collection effort, the analysis uses information about firms based in Michigan (148 firms), New York (110 firms), Ohio (99 firms), Illinois (91 firms), Indiana (79 firms), and Massachusetts (58 firms). These states were the leading locations of auto producers during the early stage that extended until the emergence of the dominant design and together they represent 585 firms or 70% of the industry.

Using the Standard Catalogue of American Cars, I identified all firms that attempted production and their entry/exit dates, the city of operation, spinoff status, and parent name. Firms who produced experimental prototypes that never commenced production are not part of the dataset. I used gazette publications, phone directories, firm records, automotive histories, autobiographies, social directories, and trade magazine announcements to identify the founding team members, and their experience before industry entry. To distinguish firms based on the operational expertise of the founders, I have also collected pre-entry work experience and subsequent auto industry work roles of founding team members based on their job titles. For example, the data allows me to distinguish between a wealthy hobbyist startup and a startup initiated by machinists who had experience manufacturing, or between investor led spinoff and a factory manager lead spinoff. An individual is assumed to have been involved in the operations of a metal factory if he served as the CEO, Vice President, or General Manager of a firm that produces metallic products. Individuals who served as board member, treasurer, secretary, chief designer, or in any other capacity that was unable to influence the production process directly were not considered to have metal factory experience.

Further, to measure scaling capacity, I used production quantity figures from the Raff-Trajtenberg (1997) dataset.[5] This dataset contains production information for all firms that entered the New York

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[5] As described in Goldfarb, Zavyalova and Pillai (2018), the Raff-Trajtenberg dataset "is based upon numbers reported in the Standard Catalogue and other sources for leading firms. While production numbers for leading firms are well known (Smith, 1968), the information for smaller firms is spotty. Sometimes only the total quantity the firm ever produced is

auto show between 1901 and 1918. The New York auto show, organized by the Automobile Club of America, was the marquee event where the public witnessed what the industry had to offer and the premier launch pad for new models (Flink, 1988: 25; Smith, 1968: 49). Annual production information during the observation period was obtained for 456 firms out of 585 firms in the dataset.

I identify firms with metal factory expertise in founding teams and statistically test their survival and scaling advantage. The dependent variable *Failure* is used to test the survival advantage using the Cox hazard model in Models 1-5. Each row in the dataset analyzing Models 1-5 represents a single year that the firm was active. *Failure* is a dummy variable that is set to 1 the year before firm failure. In Model 6 the dependent variable, *Average Annual Change in Production,* which represents the scaling capability of the firm, is measured by first calculating the annual change in production (Production in year t MINUS Production in year t-1) and then averaging it across the life of the firm during the observation period. Each row in the dataset used for Model 6 represents a single firm.[6] Negative *Average Annual Change in Production* implies that on average the firm shrank. Since the automobile industry has historically been funded by pre-orders (Flink, 1970), a negative change in production suggests either that the firms' production capability withered away or that it experienced reduced demand. During a period in which the initial demand was mostly the outcome of a good quality prototype, a reduction in previously existing demand implies that the firms were unable to do justice to the prototype in the manufacturing process. Thus, I suggest that Negative *Average Annual Change in Production* is representative of diminished scaling capabilities.

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known, but how those quantities are distributed across years is not. At other times, even this number is not known with certainty. In the former case, we assumed a distribution with a single production quantity peak and distributed the known total across the years of known activity. In the latter case, the same technique was applied, but to a "guesstimated" number based on the qualitative description in the Standard Catalogue. While we acknowledge that this implies a lack of precision, to our knowledge, this is the most comprehensive database of production quantities from the period (:2352)."

[6] Due to the extremely unusual and historic production success that Ford Motor Co. experienced during the period, it was not included in Model 6. However the results are robust to its inclusion.

The results account for the following control variables that have been suggested to influence the outcomes in this industry by prior literature (Klepper, 2007): *Detroit* representing a firm's presence in Detroit, *Spinoff* representing whether at least one founding team member worked for another auto manufacturer prior to entry, and *Firm's Parent Top Ten Manufacturer* representing whether the parent firm was among the top ten producers the year before spinoff birth. To control for entry timing, I group the firms into three cohorts: *Cohort 1*(entry before 1905), *Cohort 2* (entry from 1905 to 1909), and *Cohort 3* (entry from 1910 to 1918).

6. Results

6.1 Descriptive statistics

In Table 1, which presents the descriptive statistics for the 2416 Firm-Year dataset used for analysis in Models 1-5, the key outcome variable is *Failure*. Similarly, in Table 2, which describes the 456-firm dataset used for analysis in Model 6, the key outcome variable is *Avg. Annual Change in Production*. As predicted by prior literature, not only are *Detroit* (correlation coefficient = -0.04), *Spinoff* (-0.07), and *Firm's Parent Top Ten Manufacturer* (-0.09) negatively correlated with failure (i.e. positively correlated to survival), but earlier entrants (*Cohort 1*: -0.1) also have a higher probability of survival than later entrants (*Cohort 2*: 0.04 and *Cohort 3*: 0.07). Similarly, *Detroit* (-0.17), *Spinoff* (-0.18), *Firm's Parent Top Ten Manufacturer* (-0.25), and *Cohort 1* (0.03) displays an increased ability to scale. The high mean value of *Cohort 1* in Table 1 indicates the higher entry during the earlier period and a higher probability of survival

It should be noted that *Cohort 3* entrants (0.01) are also capable of scaling and that *Cohort 1* entrants do not appear to have an advantage over them. I suggest that during the 1910-1918 period the ability to scale was the most focused capability in the industry due to the success of the Model T. As a result, the correlation is an outcome of the fact that firms that were capable of scaling were more likely to enter during this period. Relative to other explanatory variables, *Metal Factory Experience* is more correlated to survival (-0.18) and scaling capabilities (0.30). Of the 585 firms in the dataset used to analyze Models 1-5, 112 were spinoffs, 139 firms had founders with metal factory experience, and 61 firms were spinoffs with metal factory experience. Off the 456 firms with production information that is used to analyze Model 6, 86 firms were spinoffs, 96 firms had founders with metal factory experience, and 43 firms were spinoffs with metal factory experience.

6.2 Survival analysis

Models 1-5 in Table 3 presents the results of the Cox Hazard models (Stata function: stcox) with *Failure* as the dependent variable. In this model, if the 95% confidence interval is below 1, that independent variable contributes to a higher probability of survival (or lower failure hazard). Model 1-4 replicates the findings from Klepper (2007). Model 1 suggests that relative to later entrants (Cohorts 2 and 3), earlier entrants (Cohort 1) have a higher probability of survival. Model 2 suggests that relative to firms located elsewhere, those based in *Detroit* had lower failure hazards (95% CI: [0.56,0.95]). Model 3 suggests that being a *Spinoff* (95% CI: [0.48, 0.81]) is a better predictor of survival. Model 4 suggests that when parent performance is considered, the survival advantage of *Detroit* (95% CI: [0.69, 1.20]) and *Spinoffs* diminish (95% CI: [0.56, 1.02]). It also suggests that spinoffs from better performing parents had a higher probability of survival (95% CI: [0.32, 0.90]). Model 5, suggests that controlling for all the other variables, *Metal Factory Experience* resulted in lower hazards of failure for the firm (95% CI: [0.44, 0.74]). It also suggests that the predictive power of *Detroit, Spinoffs, Parent Top Ten Manufacturer* significantly diminished when metal factory experience is considered.

The Kaplan Meier survival curves (Stata function: sts graph) presented in figure 1 indicates that, while 29% (=39 firms that survived /134 firms in the risk set) of the firms with metal factory experience survived for at least 10 years, only 7% (=31/451) of the firms without metal working knowledge survived the same period. Because the status of the firm as a spinoff may be the leading alternative explanation for survival, figure 2 presents the Kaplan Meier curves that further breaks down the firms by their spinoff status. The risk table presented in figure 2 suggests that while 35% (=26/74) of the non-spinoff firms with metal factory experience (labeled as *metal =1 / spinoff =0*) survived 10 years, only 8% of spinoff firms without metal factory experience survived (*metal =0 / spinoff =1*). Thus, the Cox Hazard models and the Kaplan Meier survival curves suggest that prior experience at metal factories was a better predictor of survival than the alternative explanations proposed by prior literature.

6.3 Effect on annual production capacity

Due to the modal nature of the production data, i.e. the significant heterogeneity in the number of vehicles produced by firms with some producing less than 100 annually and some producing thousands annually, a quantile regression is used to estimate effects (Stata function: qreg). This type of regression is more robust to the effects of outliers. With a binary predictor, the coefficient of a quantile regression is the difference in medians between groups coded 0 and 1. Model 6 suggests that, relative to the median firm without metal factory experience, the median firm with metal factory experience increased their production annually by an additional 71 vehicles. Since the other possible binary explanatory variables include 0 in their 95% confidence intervals, the difference in the median between groups of 0 and 1 are indistinguishable, i.e., other firm attributes have not offered a production advantage when metal factory experience is considered. Thus, metal factory experience has a positive and significant impact on the scaling capabilities of firms.

7. Likely explanations considered

I acknowledge that scaling may not be the only capability that matters. However, any such alternate explanation needs to align with the uncovered historical evidence. For example, to argue that failure was caused by weak final demand, an alternative explanation would need to account for the strong overall demand that characterized the early automobile market. General accounts suggest that the hype surrounding automobiles was so enormous that most firms with a functioning automobile were able to gain initial orders. At the onset of the industry, automobile manufacturers demanded advance cash deposits of up to twenty percent from the dealers with the remainder paid entirely in cash upon delivery (Flink, 1970; 294). As noted by Roy Chapin, one of the founders of the Hudson Motor Car Company, "[d]ealers' deposits often paid half the sum necessary to bring out a full year's production (Seltzer, 1928:21)." At the same time, auto manufacturers paid their suppliers only after the manufacturer completed the production and delivered the vehicle. This arrangement of cash advances and delayed supplier payments allowed the early entrants to remain solvent despite having only minimal initial cash investments (Goldfarb et al., 2012). Thus, in its earlier stages, the industry was mostly funded by customers and suppliers. The existence of the company at least for a year indicated that they had initial orders; the ability to full fill those orders, however, was heterogeneous.

It is possible that better quality ideas could be the ones that performed well and attracted the relevant expertise. For example, firms that wanted to engage in high volume production may have sought specific types of talent. However, if production expertise was a critical capability, we should also see limited discussions in archival sources about the importance of other capabilities, greater percentage of survivors to have production expertise in their founding teams by the end of the observation period, and a greater ability for firms with production expertise to increase their capacities annually. I offer evidence supporting these outcomes through my historical and statistical analysis.[7]

Perhaps not every firm wanted to scale. Firms that focused on customization, often the risk-averse firms that produced technology which solely strived to serve known consumer requirements,

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[7] If production expertise was critical, I should also observe increased mobility among production experts due to market demand for this rare competency, higher probability of mobility for production experts from failed firms relative to other employees in the same firm, and a higher probability of failing firms with production capabilities being acquired instead of going bankrupt. I am in the process of empirically verifying these predictions from the data I already collected using statistical evidence and qualitative evidence from historical records.

never engaged in mass production either because the burden of satisfying ever-changing customer demands prevented them from making the long-term investments needed to scale production, or because they preferred exclusivity. However, given the tremendous growth of the industry, firms remained exclusive even with a marginal increase in production. Any firm choosing to produce a fixed number of cars throughout their life is an outlier in this industry. Even firms attempting to focus on limited, high-status consumers should demonstrate a marginal annual growth in production capacity. An absence of such growth (as measured in Model 6), indicates an inability to scale rather than choice. Moreover, history suggests that many firms, such as Lozier Motor Car Co., that started by serving elite markets, were forced to continue to do so because they failed in their attempts to mass produce a lower-priced vehicle (Davis, 1988).

Achieving scale may also have negative consequences. Scale may result in diseconomies, i.e., "when information about a firm's capabilities is dispersed among the individuals in the firm, production is inefficient ... when people in a hierarchy exploit the bargaining power that their private information gives them (McAfee and McMillan, 1995: 400)." Scaling often requires codification and sharing of tacit knowledge within firms; however, codification may erode the competitive advantage since codification makes it easier for rival firms to acquire or imitate the knowledge (Lado and Zhang, 1998; Tsai, 2001; Rivkin 2001; Coff et al., 2006). The influx of new talent needed to achieve scale may threaten organizational culture (Harrison and Carroll, 2006). However, the historical evidence does not indicate the existence of adverse consequences of scaling in this context.

8. Implications for theories of industry emergence

An in-depth exploration of the context has revealed that the ability to manage production scaling was a specific capability that founders inherited from their pre-entry experience operating a factory that depended upon knowledge of metalworking. The analysis suggests that this experience provided founders the ability to overcome production bottlenecks through efficient use of tools and streamlined processes. I use historical narratives to offer qualitative evidence of causality and demonstrate the practical use of historical methods at the boundary of traditional inference in the absence of a dispositive statistical test of causality. I use multivariate statistics to test that predictions hold true for the general population by demonstrating the survival advantage and the annual production advantage that metal factory experience conferred on firms. This observed impediment to growth and its solution, though embedded in the context, holds valuable lessons for the field of strategy literature.

While a number of theories have strived to explain firm outcomes during the early stages of an industry, my findings have implications, predominantly, for two theories: (a) the pre-entry experience literature that uses the evolutionary economics perspective and the new venture teams perspective. (Helfat and Lieberman, 2002; Klepper, 2002; Bayus and Agarwal, 2007; Beckman et al., 2007; Klotz et al., 2014); and (b) the product life cycle theory that uses the dominant design perspective and the R&D capacity perspective (Abernathy and Utterback, 1978; Suarez and Utterback, 1995; Christensen et al., 1998; Klepper, 1996; Cohen and Klepper, 1996; Murmann and Frenken, 2006; Suarez et al., 2015). Even though my findings are necessarily less generalizable because it is based on a single industry study, the study uncovers propositions that may be tested in other contexts.

8.1 Pre-entry experience

Proposition 1: The value of founding team pre-entry experience depends on the specific capability that is inherited by the firm and the contextual relevance of that capability.

The relevance of metal factory experience in overcoming scaling issues is a context embedded finding that is not applicable to most other industrial contexts. However, the finding suggests that early industry stage firms face unique challenges to growth that may be specific to the context in which they operate in. It also suggests that the capabilities that firms need to overcome such a challenge may also be context specific. Not all pre-entry experiences are equally valuable; some endow capabilities that are more important than others (Chen and Thompson, 2015). As a result, for the literature to have predictive validity, it is critical to have a renewed focus on identifying specific, firm-level, pre-entry capabilities that matter, why this particular capability gives firms performance advantages, whether employees exploit their pre-entry knowledge, and which specific pre-entry functional experience permits learning and inheritance of these capabilities.

The literature on pre-entry experience from the evolutionary economics perspective has revealed its sustained impact on the choices and the performance of a firm (Evans and Leighton 1989; Brüderl et al., 1992; Gimeno et al., 1997; Sleeper 1998; Klepper and Simons 2000; Delmar and Shane 2006; Franco and Filson 2006; Ganco and Agarwal, 2009).[8] However, in a variety of contexts, studies have offered “conflicting empirical evidence regarding the main effect of pre-entry experience on performance (Ganco and Agarwal, 2009: 229).” Evolutionary economics studies have pointed to performance advantage of startups, diversifying entrants, and a convergence between them (for a detailed review, see Ganco and Agarwal, 2009). Diversifying entrants may have access to more resources and better integrative capabilities across firm boundaries; but often fail due to their structural inertia (Carroll et al., 1996; Klepper and Simons, 2000; Helfat and Campo-Rembado, 2016; Moeen, 2017). In contrast, startups may have fluid or organic structures and core competencies that better fit their competitive environment, but they may not be adept at the renewal and reconfiguration needed to transition to incumbency (Helfat and Raubitschek, 2000; Chen et al., 2012). The comparison of

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[8] The rich literature on pre-entry experience suggests that firms inherit a variety of skills from their founders that subsequently affects their performance. Firms inherit human resource and employment blueprints (Baron and Hannan, 2002, 2005), technological and market knowhow (Agarwal et al., 2004), and non-technical knowledge related to regulatory strategy and marketing (Chatterji, 2009) from the prior experience of its founding team members. Pre-entry experience allows firms to overcome the liability of newness by providing access to capital (Gompers et al., 2006), and by signaling trustworthiness (Eisenhardt and Schoonhoven, 1996), reputation (Burton et al., 2002), legitimacy (Stuart et al., 1999), and technological relevance (Podolny and Stuart, 1995). It also allows businesses to overcome growth impediments (Chen et al., 2012) by providing companies the capacity to reposition and adapt (Eggers, 2014), by influencing the firm's ability to identify market opportunities (Gruber et al., 2013), and by increasing the likelihood of diversification (Wu, 2013). It facilitates survival even when companies lose early stage technology competition (Furr et al., 2018).

various measures of performance may further convolute the effect of pre-entry experience. For example, the finding that start-ups introduce product innovations at a higher rate than diversifying entrants but nonetheless also fail at a higher rate (Khessina, 2002; Carroll and Khessina, 2005) makes it difficult to decipher what the ideal strategy is.

Similarly, the new venture teams (NVT) literature, has also revealed the impact of founding team's prior experience on firm-level outcomes (Eisenhardt and Schoonhoven, 1990; Beckman 2006; Beckman et al., 2007; Chowdhury, 2005; Klotz et al., 2014).[9] Prior research has explored the impact of the founding team's characteristics on short-term outcomes and the effect of imprinting on long-term consequences. However, the new venture team literature "know[s] quite little about how and when NVTs influence[s] the [firm] performance (Klotz et al., 2014: 229)." This is due to its lack of focus on collecting primary data needed to understand team-level mediating and moderating mechanisms (For a detailed review, see Klotz et al., 2014). Moreover, these studies often offer uncertain predictions on the founding team composition. For example, the pre-entry experience could be more or less beneficial to firms depending on the characteristics of the founding team (Zheng et al., 2016). While diverse founding teams have access to a broader set of information that they use to enhance performance through explorative behavior (Beckman, 2006), homogeneous teams excel in execution speed and engage in exploitative behavior (Baum and Wally, 2003; Kor, 2003; Fern et al., 2012). Founding team characteristics such as alignment of functional experience with competitive strategy (McGee et al., 1995; Shrader and Siegel, 2007) and educational diversity (Foo et al., 2006; Amason et al., 2006) has also been suggested to have contradictory performance outcomes. Pre-entry activities could even have detrimental effects in dissimilar contexts since they create strong biases and overconfidence rooted in inadequate information (Mulotte et al., 2013).

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[9] The new venture teams literature has characterized prior experience using factors such as company affiliation (Beckman, 2006), educational prestige (Lester et al., 2006), success (Nelson, 2003), and employment background (Amason et al., 2006).

Recognizing specific capabilities that matter may not only resolve some of the contradictions and partial explanations offered by the theories explaining performance in early industries, but also offer practical advice to entrepreneurs. For example, I suggest that the contradictory evidence offered in the pre-entry capabilities literature is due to a lack of focus on specific capabilities, and how their relevance changes as the industry evolve. Studies that identify specific pre-entry skills that matter, such as management skills (Dencker et al., 2009), engine manufacturing (Thompson, 2001), and financial management (Brinckmann et al., 2011), are rare. The literature uses prior employment to represent the presence of relevant skills. However, even though each employment opportunity provides individuals with a variety of skills, the literature rarely identifies which skills are relevant or how that skill translates to a specific action that the firm engages in. Because the specific skills needed to succeed may be gained either from firms in the same industry or others, these skills could be spread across both startups and diversifying entrants.

From a new venture team perspective, identification of specific capabilities may help partially resolve the diversity vs. homogeneity debate. Having similar education or overlapping experience in a firm does not necessarily mean that the individuals possess the same skills. Focusing on specific capabilities rather than making assertions on capabilities based on team priors may better explain the performance difference between teams. It may also help the literature progress towards understanding why certain types of teams may be more useful than others at certain stages of the firm/industry, and understanding how specific team processes influence firm performance.

8.2 Product life cycle

Proposition 2: Process innovations, due to their influence on the firm's product choices and market size, are critical to the firm performance from the early stages of an industry.

Process innovation has been described as the "grubby and pedestrian side of the innovation process (Rosenberg, 1982)," as the "most primitive form of innovation (Tushman and Rosenkopf, 1992: 313)," and as "a second-order innovative activity, a rather dull and unchallenging cousin of the more glamorous product innovation (Reichstein and Salter, 2006: 653)." However, this study reveals that process innovation may be critical much earlier and may have a greater impact on the early stages of an industry than previously thought.

In the dominant design perspective of the product life cycle literature, firm success depends initially on their ability to uncover the dominant product design and subsequently on their ability to incorporate the dominant process design (For a detailed review, see Murmann and Frenken, 2006). This model treats early industry stage product experimentation to be a stochastic process driven purely by exogenous technological factors. In this model, after the market converges to a single dominant design through a process of competitive elimination of products, firms shift from product to process innovation resulting in price competition. The literature characterizes process innovations as being merely consequential during that the mature stage price competition.

However, the early automobile industry suggests that production processes influenced product design choices. Firms that were adept at managing the scaling problem strived to design products in a manner that improved production efficiency. Production process innovations were critical for the organization because it biased the scope of the product innovations. Because 'how to produce' was a strong determinant of 'what to produce', firms were not merely competing on non-stochastic technology choices during the early stages of the industry. After all, "[d]ominant design is not a product, but a way of doing things which is manifested in a product (Lee et al., 1995: 6)." In this context, technical capabilities were necessary, yet insufficient for firm performance. By taking a selection perspective where survival is predicated on technology choice and timing of entry, the dominant design literature may have undermined the importance of process innovation.

Thus, even though the dominant design literature has described competitive advantage to be the "result of the fortunate combination of technological, economic and organizational factors (Suarez and Utterback, 1995; 416)," it has predominantly focused on the technological aspects. The technology focus of this literature fails to acknowledge that "[f]irms rarely fail because of an inability to master a new field of technology, but because they do not succeed in matching the firm's systems of coordination and control to the nature of the available technological opportunities (Pavitt, 1998: 433)." Moreover, the finding that process innovation is important even during a period of intense product innovation conforms to studies that have described the process and product innovations to be complementary (Martinez-Ros, 2000; Damanpour et al., 2001; Reichstein and Salter, 2006).

In the R&D capacity perspective of product life cycle theory, firms create competitive advantage by achieving production scale economies. Venture costs depend solely on process R&D, and the firm's process R&D investments are proportional to its size. As a result, average unit costs and marginal profits vary based on the market share. As existing firms grow, the minimum viable scale also increases thereby making it harder for new firm entry. In this model, a standard product exists from the outset and the consumer choice depends solely on the market share. However, the importance of process innovations in overcoming scaling challenges encountered during the early automobile industry suggests that process innovations are essential to achieving market share. The assumption that market share precedes process innovation does not hold true in at least this context. Moreover, this model's assumption that a standard product exists from the outset undermines the key role process innovations play in determining the product.

9. Value of contextual richness in studies of industry emergence

The automobile industry is one of the most studied contexts in the field of strategy, with numerous scholars making many valuable findings. This study is able to generate unique novel insights despite the existence of a rich literature on the same industry because it engaged in an in-depth exploration of the industrial context. Recognition of the impediments to growth and the specific capability that firms needed to overcome this impediment require an intimate understanding of the underlying mechanisms that can only be gained from contextual knowledge. However, this study does not intend to criticize prior studies on the automobile industry. This study has been aided immensely by the valuable insights prior automobile industry studies have offered. My study is able to extend work in this in part due to advances in digitization at the major automobile industry archives that provided access to records that were often unavailable to prior scholars.

Theories in strategy accurately derive many generalizable results that explain early-stage firm performance. However, they are often constrained in their ability to advise entrepreneurs on specific capabilities entrepreneurs need to have or specific actions they need to take. These theories often struggle to capture the difficult decisions entrepreneurs need to make when faced with the unpredictable demand fluctuations and the discontinuous technological changes that characterize early-stage industries. Indeed, during this stage, this uncertainty is often a higher threat to survival than either environmental complexity or munificence (Anderson and Tushman, 2001).

An outcome of these theories' lack of specificity is that, even though the lessons from these theories are valuable, the theories' ability to advise entrepreneurs may often be severely limited. For example, technology management literature's focus on an industry level ex-post analysis of factors that may have influenced the dominant design has come at the cost of exploring specific actions that firms may take ex-ante to influence the dominant design. This limits the theory's ability to offer entrepreneurs timely advice on when to enter, or what technology to pursue. Similarly, while it is evident that pre-entry capabilities matter, the theory faces limitations when offering insights to individuals on which capability they should focus on, when, and why. From a new venture team perspective, it struggles to conclusively advise entrepreneurs what the team characteristic should be, at what stage are some characteristics more important, and what effects are driven by the team as a unit or by individual members.

Thus, these theories are confronted with the 'postulate of commensurate complexity' whereby they are unable to simultaneously achieve generalizability, accuracy, and simplicity (Thorngate, 1976). Indeed, they mostly trade the realism of context for generalizability to the population and measurement precision (Scandura and Williams, 2000). In practice, this often means that the studies focus on findings that can be applied to multiple industry contexts rather than embedded generalizations that are only applicable to a unique environment. However, partial analyses of complex phenomena render partial explanations that may be mutually inconsistent resulting in excessive truth claims and extreme assumptions for the sake of generalizability. This has diminished not only the impact of theory on practice but also the impact of business education on business outcomes of students (Leavitt, 1989; Hambrick, 1994; Mintzberg and Gosling, 2002; Donaldson, 2002; Pfeffer and Fong, 2002). At its worst, the partial explanations and ambiguous theories could even have adverse effects on good management practices (Ghoshal, 2005) – a concern amplified by the finding that 29% of the published results are non-replicable (Goldfarb and King, 2016).

Development of richer theories that incorporate the complexity of context, rather than simple reductionist prescriptions which consider premises as an underlying assumption, may serve to offer more valuable insights for practitioners. As noted by Oxley et al. (2010), "the single most important change the field should make to improve quality is to increase the level of specialization in strategy research (:378)." This requires scholars to invest in gaining in-depth contextual knowledge rather than merely engaging in a single industry study. Such rich contextual knowledge not only reveals how and why transformational changes occur, but also how often and how many actors undergo such changes. Deep knowledge about the environment also establishes the context in which to evaluate various revealed relations and helps scholars gauge the strength of the relations.

Further, I also propose the use of historical methods as a tool to engage in an in-depth exploration of a context. identify specific capabilities that matter and to identify how they translate to firm actions. Historical methods can be described as "empirical research that uses remote sensing [as opposed to direct observation] and a contextualist [as opposed to reductionist] approach to explanation (Ingram et al., 2012: 249)." It refers to the use of systematic practices in analyzing and interpreting historical artifacts, documents, and images. Historical research often begins with historically significant phenomena rather than theoretically framed questions. (Lipartito, 2014). Instead of offering universal generalizations deciphered from dependent and independent variables relevant at a particular moment in time, historical reasoning provides embedded generalizations and theoretical claims within narratives by recognizing the interdependencies and evolving direction of causality between variables over time (Gaddis, 2002). Historical methods orient towards theory building rather than hypothesis testing, towards usage of small samples that are often limited by access rather than random sampling, and towards exploring phenomena to uncover unexpected results rather than measuring marginal effects or outcomes (Yates, 2014). Thus, historical inference views actions and actors as temporally situated and is bound by the limits of the context.

Moreover, the historical inference is well suited for the analysis of the operation of pre-entry capabilities in early-stage industries. It can be utilized as a source of exogenous variation that allows better causal inference, and as a source of legacies that enhances analyses of path dependence (Ingram et al., 2012). History can be particularly useful for this literature because it excels in areas where existing research methods have encountered difficulties. Because historical methods can take outliers seriously, historical inference often uncovers mechanisms at work during early industry stages that do not fit existing theoretical models (Bates, 1998; Hansen & Libecap, 2004; Silverman & Ingram, 2017). Historical methods allows application and development of theory to reveal the operation of transformative social processes, explains the form and origins of significant contemporary phenomena, disambiguates among competing explanations, and thus contributes towards the study of the emergence of new industries (Forbes and Kirsch, 2011; Maclean et al., 2016).

10. Discussion

In this study, I suggest that firms whose founding team members had prior operational experience in a factory that produced metallic products were able to overcome production bottlenecks and thereby achieve scale. I restrict my focus to one crucial challenge that entrepreneurs faced in a single industry at a particular stage. I engage in a broad reading of the archives of the industry using historical methods to reveal the underlying characteristics of the challenge and the specific role metal factory experience played in enabling firms to overcome them. Thus, the findings are necessarily less general and embedded in the context of the study. However, I strive to offer a richer understanding of the challenge and the value of a specific experience.

This study focuses exclusively on the early stages of the industry. Prior industry emergence studies have often either grouped together earlier and later stages of an industry or focused exclusively on mature stages of an industry, thereby limiting our understanding of the mechanisms that are unique to the early stage. Due to the availability of fewer records from the earliest stages of an industry, archival sources used for these studies are not neutral with respect to outcomes. Researchers encounter information that has been retrospectively reordered to emphasize what is understood to be important *post hoc and may, therefore, miss important paths-not-taken and their implications for the industry as it did emerge* (Kirsch et al., 2014; Lipartito, 2014).[10] The combination of multi-stage grouping and retrospective sensemaking may result in misestimation or underestimation of the significance of certain early stage phenomena. By utilizing comprehensive knowledge of the early stage industry context, this study is able to offer insights that are minimally influences by the biases of the mature stage outcomes.

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[10] For example, in studies of automobile industry emergence, the 1899 US Census Bureau report which states that the number of gasoline cars sold trailed both steam and electric has been cited often to support a wide range of claims and counterclaims (Kirsch et al., 2014). However, the retrospective bias of these studies prevented them from noting that, in 1899, when the automobile industry was at its infancy, the census bureau grouped together firms that sold vehicles and those that sold transportation services (Kirsch and Mom, 2002). As a result, scholars may have overestimated the significance of electric and steam vehicles to fit their respective theoretical narratives.

Few studies have identified specific pre-entry capabilities that matter and the specific actions they influence. This study contributes to this literature by identifying a specific pre-entry capability that contributed to performance advantage. I suggest that 'What experience matters?' is a relevant question that should be asked in other contexts. The capabilities needed to overcome bottlenecks to growth are expected to vary across contexts since the nature of the bottlenecks are also expected to vary. The literature on pre-entry capabilities needs to offer more specificity by identifying what knowledge is valuable, why, in what context, and from where firms inherit this knowledge. This knowledge could be particularly powerful for managers in contemporary contexts. Thus, the process of scaling needs to be studied at this level of specificity in *other* contexts to uncover the range of potential underlying mechanisms that limit and enable growth.

It should be noted that other studies have explored the importance of pre-entry capabilities in the automobile industry. Klepper (2007) suggests that spinoffs have lower hazards of exit than other startups due to the industry-specific knowledge they inherit, and that a parent firm's performance was a predictor of spinoff performance. Argyres and Mostafa (2016) suggest that, in the automobile industry, the strategic choice to vertically integrate key value chain activities enhanced survival duration and that the integration choices of the parent predicted those of the spinouts. Carroll et al. (1996) argue that diversifying entrants, and startups that spend time acquiring sufficient resources before entry had lower initial mortality rates. Supporting the longevity advantage offered by pre-entry capabilities, Hannan et al. (1998) suggest that even as firms aged, the mortality rates of diversifying entrants and spinoffs remained unaffected. Bigelow and Argyres (2008) suggest that pre-entry experience significantly affected make-buy choices in the automobile industry. Yet, these studies have not identified specific pre-entry capabilities/resources that firms inherit or how they translate to firm actions and how those firm actions result in a performance advantage. My study does, however, align with the results of Thompson (2001), who, in his study of the shipbuilding industry from 1824-1914, suggests that entrants with prior vessel construction or engine manufacturing experience survived longer than firms with unrelated foundry experience.

This study challenges key predictions of the product life cycle framework. Unlike the prediction that the firm's product innovations and market size precedes process innovations, this study suggests that process innovations are critical for firms from the early stages of an industry due to their influence of product innovations and market size. This study joins others, who in a variety of industry contexts, have challenged other predictions of the product life cycle theory. Studies on publicly traded US firms (McGahan and Silverman 2001), and industry-specific studies on the amateur camera (Windrum 2005), turboprop engine (Bonaccorsi and Giuri 2000), microelectronics (Filson 2001), personal computers (Filson 2002), and mobile phones (Giachetti and Marchi 2010) have suggested deviance from the predictions of the product life cycle framework. Future research can explore how and why process innovations are adopted, designed, and executed at the various stages of an industry, and how this may affect the evolutionary trajectory of industries.

The revealed significance of metal factory experience adds a further dimension to the rich management literature that has investigated how capable managers and the adoption of managerial practices have a profound effect on the productivity of plants. The capabilities of strategic decision makers responsible for operating a factory have a lasting effect on the plant's ability to achieve scale, and subsequently, profits. As early as 1887, on the first volume of *Quarterly Journal of Economics*, describing the significance of efficient production, Francis Walker wrote: "surplus, in the case of any employer, represents that which he can produce over and above what an employer of the lowest industrial grade can produce with equal amounts of labor and capital. In other words, this surplus is of his own creation (274)." Innovative management practices have been associated with plant productivity (Ichniowski et al.,1997). Analyzing a sample of 1500 publicly traded US firms, Bertrand and Schoar (2003) found that there are significant manager fixed effects on performance. Examining the limited liability firms from Denmark, Bennedsen et al. (2007) discover that professional managers outperform managers with familial ties. In their field experiment with Indian textile plants, Bloom et al. (2013) show that the adoption of management practices raised productivity. Using survey results from German manufacturing plants, Bender et al. (2018) find that firms with better managers had a superior stock of employees. Braguinsky and Hounshell (2016) found that superior managerial talent of a single firm allowed it to make strategic decisions about technology that not only made it highly productive but also put the industry on a high growth trajectory. However, unlike this study, this literature has not examined the mechanisms for reaching scale economies under the uncertainties and constraints imposed on firms during an industry's earliest stages.

This study suffers from a number of potential limitations. (1) It assumes that resources and routines accessed by individuals in their prior experience can be successfully transferred and replicated in new contexts. However, some firm capabilities may be less decomposable and portable (Baldwin and Clark, 2002). (2) Except in the case of prior experience within the automobile industry, this study does not consider the success of the prior firms in its analysis. It is possible that more successful prior employers had better knowledge to impart on its employees. As a result, we may expect heterogeneity in outcomes based on the quality of prior non-automobile industry employer of the founder. (3) The study does not consider hiring capabilities that may mediate the influence of founder's experience on firm outcomes. For example, during the early 1900's, hiring an effective foreman and having access to skilled labor may have had an impact on the execution capabilities of the founder. (4) The paper does not explore the role of inherited assets; it only considers inherited knowledge. Founders' ability to re-purpose assets such as tools, factory facilities, and employees from their prior businesses may reduce initial firm costs and thereby have an impact on firm outcomes. (5) While the study offers qualitative evidence that suggests the importance of process innovations, it does not measure process innovations. The study theorizes about the role of process innovations without statistically testing it.

Ongoing data codification efforts are expected to offer quantitative and historical evidence that addresses these limitations.

11. Conclusion

This paper analyzes a specific stage of an industry that was of great economic importance using quantitative and historical methods to offer findings that may be tested in other contexts. This study suggests that the capabilities inherited from some pre-entry experiences are more important than others for firms to overcome growth bottlenecks. It also suggests that process innovations, due to their influence on product innovations and on scaling capabilities, may be critical from a very early stage of an industry. Thus, the study suggests that, if bottlenecks to growth exists in early stage industries, the capabilities needed to overcome those bottlenecks are context specific.

Further, the study also demonstrates that the historical explanation is an effective tool that scholars can use to infer to the best explanation in an abductive study. The quest for generalizability and statistical causality of relations in the Strategy literature has often led to inconsistent, ambiguous findings that are devoid of knowledge about the unique interdependencies that characterize each context. In contrast, this study demonstrates that historical explanation offers a more meaningful understanding of what the likely explanations are, and a systematic, scientifically rigorous method to determine the loveliest explanation from among them.

12. Tables and figures

Table 1: Correlations - all the firms in the sample

		Mean	Min	Max	1	2	3	4	5	6	7
1	Failure	0.20	0	1	1						
2	Metal Factory Experience	0.36	0	1	-0.18	1					
3	Spinoff	0.21	0	1	-0.07	0.28	1				
4	Detroit	0.17	0	1	-0.04	0.19	0.38	1			
5	Firm's Parent Top Ten Manufacturer	0.10	0	1	-0.09	0.27	0.63	0.42	1		
6	Cohort 1 (Entry before 1905)	0.40	0	1	-0.10	0.12	-0.21	-0.16	-0.12	1	
7	Cohort 2 (Entry from 1905 to 1909)	0.35	0	1	0.04	-0.05	0.11	0.05	0.08	-0.62	1
8	Cohort 3 (Entry from 1910 to 1918)	0.20	0	1	0.07	-0.08	0.12	0.12	0.04	-0.45	-0.42

N(Firm-Year) = 2416; # of Firms = 585

Table 2: Correlations – firms with known manufacturing data within the sample

		Mean	Min	Max	1	2	3	4	5	6	7
1	Avg. Annual Change in Production	118	-3000	5916	1						
2	Metal Factory Experience	0.21	0	1	0.30	1					
3	Spinoff	0.19	0	1	0.18	0.37	1				
4	Detroit	0.16	0	1	0.17	0.19	0.28	1			
5	Firm's Parent Top Ten Manufacturer	0.07	0	1	0.25	0.31	0.56	0.19	1		
6	Cohort 1 (Entry before 1905)	0.26	0	1	0.03	0.04	-0.15	-0.10	-0.10	1	
7	Cohort 2 (Entry from 1905 to 1909)	0.39	0	1	-0.04	0.01	0.02	-0.02	0.04	-0.5	1
8	Cohort 3 (Entry from 1910 to 1918)	0.35	0	1	0.01	-0.04	0.12	0.11	0.05	-0.44	-0.58

N = 456 (# of Firms)

Table 3: Results

	Model 1 - Cox DV: Failure	Model 2 - Cox DV: Failure	Model 3 - Cox DV: Failure	Model 4 - Cox DV: Failure	Model 5 - Cox DV: Failure	Model 6 – Quantile Reg. (0.5 percentile) DV: Avg. Ann. Prod. Chg.
Cohort 2 (Entry from 1905 to 1909)	1.31 [1.05, 1.64]	1.34 [1.07, 1.68]	1.42 [1.13, 1.78]	1.42 [1.14, 1.78]	1.33 [1.06, 1.67]	-1 [-26, 24]
Cohort 3 (Entry from 1910 to 1918)	1.43 [1.12, 1.83]	1.50 [1.10, 1.68]	1.60 [1.24, 2.05]	1.58 [1.23, 2.04]	1.50 [1.16, 1.92]	-1.1 [-25,25]
Detroit		0.73 [0.56, 0.95]	0.85 [0.64, 1.12]	0.92 [0.69, 1.20]	0.92 [0.70, 1.22]	0 [-29,29]
Spinoff			0.62 [0.48, 0.81]	0.75 [0.56, 1.02]	0.85 [0.64, 1.15]	4 [-28,36]
Firm's parent top 10 manufacturer				0.54 [0.32, 0.90]	0.64 [0.38, 1.08]	14 [-13, 41]
Metal factory experience					0.57 [0.44, 0.74]	71 [23, 118]
N (Firm-Year)	2416 (Firm-Years)	2416 (Firm-Years)	2416 (Firm-Years)	2416 (Firm-Years)	2416 (Firm-Years)	456 Firms
95% CI in Parentheses	# of Firms = 585; # of Failures = 483					

Figure 1: Kaplan-Meier survival estimates (metal working only)

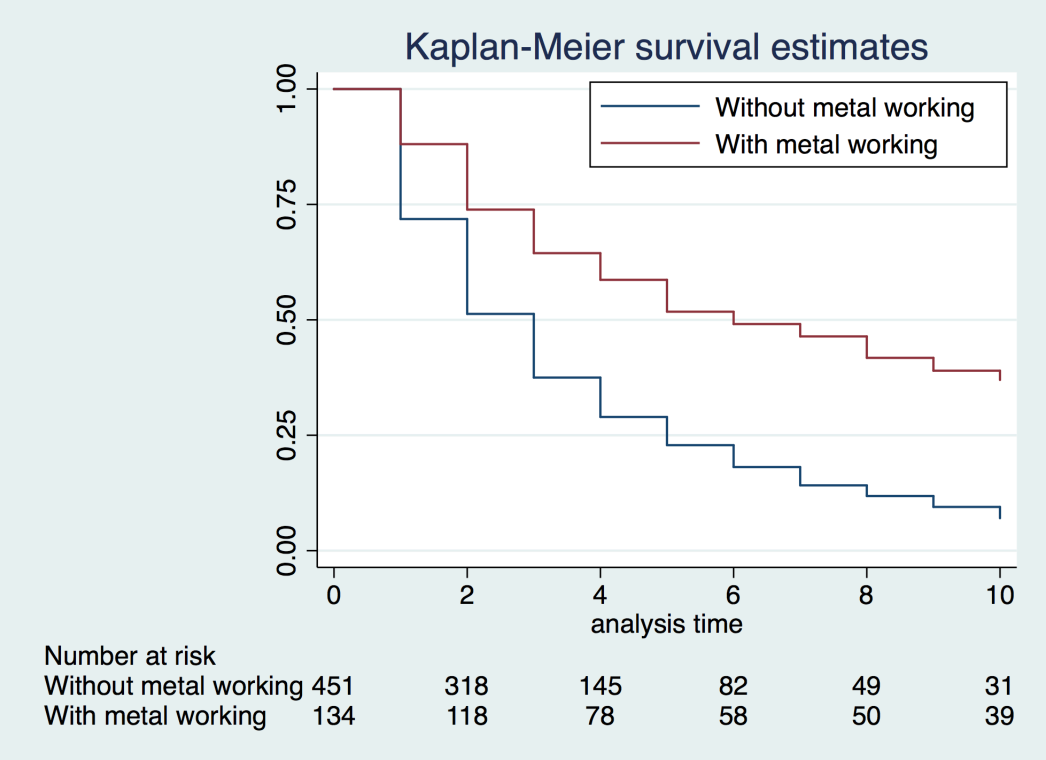
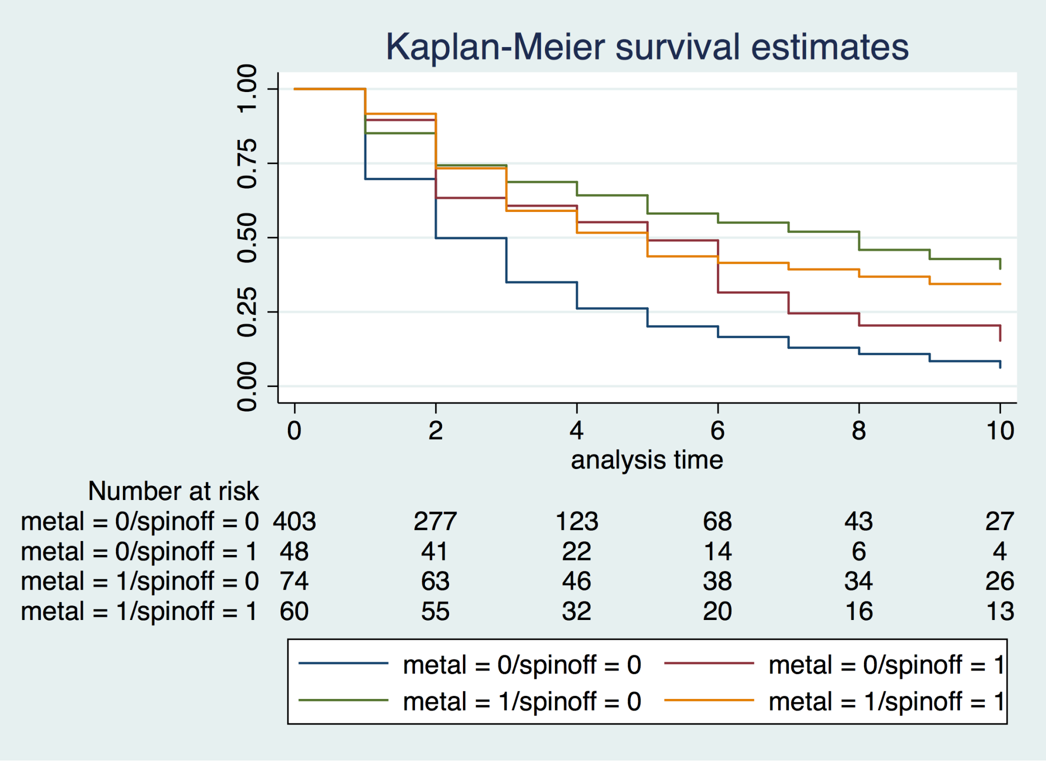


Figure 2: Kaplan-Meier survival estimates (metal working and spinoff status)



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