The Origin and Growth of Industry Clusters: The Making of Silicon Valley and Detroit

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Abstract: Data for all producers of automobiles and integrated circuits on their origins, base location, and performance are used to analyze the factors behind the historical clustering of the two industries in Detroit and Silicon Valley respectively. Key ideas concerning organizational reproduction and heredity are elaborated and used to explain how spinoffs from incumbent firms in the same industry can lead to clustering. Findings concerning the spawning of spinoffs, entry by firms in related industries, and firm performance suggest that organizational reproduction and heredity were the primary forces underlying the clustering of the two industries.

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I. Introduction

Arguably the two most impressive industry clusters in the history of the United States are the semiconductor industry in Silicon Valley and the automobile industry in Detroit. Silicon Valley got its name from the semiconductor industry and Detroit's moniker as the Motor City was derived from the automobile industry. At the start of the semiconductor industry in 1950, the population of Santa Clara County, the heart of Silicon Valley, was .3 million people. In the next 30 years, nearly 100 semiconductor firms entered in Silicon Valley, including five of the industry's top 10 firms, and the population of Silicon Valley more than quadrupled to 1.3 million. In its heyday, Detroit's growth was even more impressive. During the first 30 years of the automobile industry, over 100 automobile firms entered in the Detroit area, including over half of the industry's leaders, and the population of Wayne County, the home of Detroit, swelled from .3 to 1.8 million people.

Such extreme industry clusters are rare (Ellison and Glaeser [1997]) and call out for explanation, particularly when there is no obvious geographic rationale for the clustering. Yet there has been little systematic empirical analysis of the forces that caused the semiconductor industry to be so concentrated in Silicon Valley,[1] and until recently the same could be said about the automobile industry and Detroit. Numerous articles and books have been written about the rise of Silicon Valley, including the well known book by Saxenian [1994] concerning the triumph of Silicon Valley over Route 128 and the recent history of the semiconductor industry in Silicon Valley by Lecuyer [2006]. They lay out a theory that resonates with modern theories of geography. Once semiconductor firms began to congregate in Silicon Valley after the emergence of Fairchild Semiconductor as a leader of the industry, labor pooling, technological spillovers, and a rich supplier industry stimulated further firm growth and entry of semiconductor firms in the Valley. While this was not the story told historically about Detroit and the automobile industry (cf. May [1975], Rae [1980]), the failure of any consensus to emerge has left the door open for explanations based on modern theorizing (Tsai [1997]).

The main purpose of this paper is to bring together data collected and analyzed by Klepper [2007, 2008] for U.S. automobile entrants and Klepper [2009] and Klepper, Kowalski, and Veloso [2009] for U.S. semiconductor entrants to compare the factors behind the geographic clustering of the two industries. These data include information about the origins of the entrants, including whether they produced other products prior to entry, and for new firms whether they were spinoffs, defined as firms whose founders previously worked for another firm in the same industry. Spinoffs have been celebrated in the semiconductor industry (Lindgren [1971], Saxenian [1994], Sporck [2001], Lecuyer [2006]) and implicated by industry insiders as key to the clustering of the industry in Silicon Valley (Sporck [2001], Moore and Davis [2004]). Klepper [2007] argued that spinoffs were also key to the clustering of the automobile industry around Detroit.[2] The analysis focuses on the role of spinoffs, and more broadly organizational competence and heredity, in the evolution of the Detroit automobile and Silicon Valley semiconductor clusters.

Key ideas concerning organizational reproduction and heredity based on a theoretical model in Klepper [2008] are elaborated and used to explain how spinoffs can lead to clustering. The theory has a number of implications regarding entry and firm performance that are used to analyze the evolution of the automobile and semiconductor industries. The findings for the two industries suggest that spinoffs, and more broadly organizational reproduction and heredity, were key to their geographic clustering. A firm's pre-entry experience critically shaped its performance and its performance in turn influenced the rate at which its employees left to form spinoffs. Detroit and Silicon Valley each had an early exemplary performer that got the spinoff process going in their regions. Subsequently, better firms reproduced at a higher rate and their offspring were superior performers. With spinoffs not venturing far from their geographic origins, this led to a buildup of superior firms in Detroit and Silicon Valley. In both regions, this superiority manifested itself at the time of entry; in autos, the superior performance of firms in the Detroit area was due to the disproportionate number that descended from the

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[1] See Scott and Angel [1987], Fallick, Fleischman, and Rebitzer [2006], and Ketelhöhn [2006] for three relevant analyses.

leading firms and entered at the largest sizes, and in semiconductors the superior performance of Silicon Valley firms was due to the disproportionate number that descended from the leading firms and the greater propensity of Silicon Valley firms to enter at the technological frontier.

The role played by the spinoff process in the clustering of both industries suggests that heritage and not regional advantage was the key to their clustering. The evidence also indicates, however, that the spinoff process operated more intensively in Detroit and Silicon Valley, raising the specter of some kind of influence of regional conditions on entry. Numerous other questions are raised by the importance of spinoffs in the two clusters. Most fundamentally, why do spinoffs occur? Furthermore, why is the performance of spinoffs and their "parents" related, how do spinoffs contribute to the growth of regions, do the findings for semiconductors and automobiles pertain to other industries as well, and is the formation of spinoffs influenced by public policies bearing on employee mobility? While definitive answers are hardly available, hopefully the questions will help frame future investigations concerning the emergence and growth of industry clusters.

The paper is organized as follows. In Section II, the data used to analyze each industry is discussed. In Section III, the broad evolution of the two industries and their clusters is reviewed. In Section IV, the theoretical framework used to analyze the data is presented. In Sections V and VI, entry and performance of auto and semiconductor firms respectively are analyzed. In Section VII, the findings are discussed and various theoretical and policy-related questions are raised and considered.

II. Data

The analysis of both industries begins with their commercial inception, which is dated as 1895 for automobiles and 1949 for semiconductors.

Data on U.S. automobile producers were compiled from Smith [1968], which lists the names and base locations (state and city) of producers of each make of

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[2] Buenstorf and Klepper [2009] also feature the role spinoffs played in the clustering of the U.S. tire industry historically around Akron, Ohio.

automobile that was manufactured in the United States from 1895 to 1966.[3] Entry and exit dates of producers are based on the first and last year of production of all makes they produced. Smith [1968] reports mergers and acquisitions involving both automobile and non-automobile producers. Firms that were acquired by non-automobile firms are treated as continuing producers of automobiles. Acquisitions and mergers by automobile firms are treated as continuations of the firm whose name was retained or in the case of mergers the largest firm involved,[4] with the other firms treated as exits (see Klepper [2002]).

Data on U.S. semiconductor producers were compiled from annual listings of producers of various semiconductor and related products in the *Electronics Buyer's Guide* (*EBG*) for 1949 to 1987, where 1987 is the last year the *EBG* was published. The *EBG* listed producers of transistors, the main initial product of the semiconductor industry, from 1949 to 1987, and producers of semiconductor diodes from 1952 to 1987. Over time, further breakdowns of both categories were provided; for example, beginning in 1956 separate listings are provided for germanium and silicon transistor producers. The *EBG* began listing producers of integrated circuits (ICs) in 1965, a few years after they were first commercially produced. Separate listings were provided for different types of ICs, including monolithic ICs (all components are made on doped semiconductor substrates), hybrid ICs (a mixture of conventional components and semiconductor substrates), and film ICs (composed of layers of film on top of semiconductor substrates), with further breakdowns within each category provided, particularly as new ICs were introduced over time. In its listings of semiconductor producers, the *EBG* also drew

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[3] Smith [1968] restricted his list to firms that manufactured a car and sold to the general public. His dates are based on the years makes of automobiles were produced and his listings reflect changes in the base locations of producers.

[4] Generally it was straightforward to implement these rules. The principal exception concerned Chrysler Corporation. Chrysler evolved out of Maxwell Motor Co. and Chalmers Motor Co. when Walter Chrysler, formerly the president of Buick, was called in to reorganize Maxwell, which had recently merged with Chalmers. Maxwell was descended from Maxwell-Briscoe, which was a 1904 entrant that was the centerpiece of the unsuccessful 1910 United States Motor Co. merger organized by one of its founders. Maxwell emerged from the ruins of United States Motor Co. and regained a leading position in the industry until it floundered and Walter Chrysler was brought in to reorganize it. Accordingly, Chrysler Corporation was treated as the lineal descendant of Maxwell-Briscoe.

attention to the category of active module producers, which it began listing in 1961.[5] These various listings were used to compile entry and exit dates and base locations (state and city) for producers of transistors, diodes, ICs, and active modules,[6] with the listings of the more disaggregated products used to identify the types of each product that were produced annually by each firm.

Key to the analysis of entry and firm performance in the two industries is tracing the origin of entrants. In automobiles, 725 firms entered between 1895 and 1966. The pre-entry experience of every entrant was traced primarily from Smith [1968], which identifies whether an entrant produced other products before automobiles, and the *Standard Catalog of American Automobiles* (Kimes and Clark [1996]), which provides a short description about the origins of every firm that ever produced an automobile. Three types of firms are distinguished: diversifiers, spinoffs, and (other) startups. Diversifiers are defined as pre-existing firms that added automobiles to their product line or firms that were founded by individuals that previously headed pre-existing firms.[7] For each diversifier, its main product prior to entering automobiles is identified from the *Standard Catalog*. Spinoffs are defined as firms with one or more founders that previously worked at another automobile firm on Smith's list. The prior employer of the main founder is designated as the spinoff's parent, and if the main founder worked at a prior firm on Smith's list or a secondary founder worked at another firm on Smith's list, that firm is

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[5] The term active modules is not defined, but it appears to correspond to modules of assembled discrete components such as transistors, resistors, and capacitors that could be plugged into, for example, circuit boards.

[6] Foreign-based firms with a presence in the U.S. were listed but excluded from the analysis. Some firms had multiple entries in some years and these were consolidated into one listing at what appeared to be the main listing for the firm over time. In some instances a firm was inexplicably not listed for some period of time, and when other sources reflected that the firm produced in that period the entry was corrected. The list of IC producers was compared to the semiconductor firms in Silicon Valley listed in the Silicon Valley genealogy and the firms listed annually in the reports by ICE on the sales of the leading U.S. semiconductor producers (see below). Some firms that entered toward the end of the 1965-1987 period showed up on the Silicon Valley Genealogy and the ICE lists but not in the *EBG*, suggesting a lag in the initial listings of IC producers in the *EBG*. A few prominent firms that entered later in the period, including Micron and VLSI, never showed up in the *EBG*.

[7] Many firms entered the automobile industry with very similar but not exactly the same names as pre-existing firms. It was often difficult to tell whether they were new firms organized by the head of the pre-existing firm with the similar name or pre-existing firms that modified their names to reflect an expanded product line when they diversified into automobiles. Previously an attempt was made to separate these two types of firms but they performed similarly (Klepper [2007]), and for simplicity they are combined here.

designated as a secondary parent of the spinoff.[8] All other entrants were lumped into a residual category labeled startups.

The clustering of the semiconductor industry around Silicon Valley occurred in the IC era and so attention was devoted to tracing the origin of the 623 IC entrants between 1965 and 1987. No single source was available to do this, which limited the firms whose origins could be identified. Using the listings of transistor, diode, and active module firms, all IC entrants that previously produced these products were identified. The *EBG* lists the producers of all types of electronics products, and the annual directory of all listed firms was used to determine other IC entrants that produced some other kind of electronic product before ICs and the initial year of production of the product. The rest of the IC entrants were largely expected to be new firms. For Silicon Valley, a genealogy was compiled by the organization SEMI indicating the founders of every semiconductor entrant in Silicon Valley between 1955 and 1986. Nearly all of these firms were spinoffs, and the genealogy was used to identify the IC entrants in Silicon Valley that were spinoffs and their parents, defined as the prior semiconductor employer of the spinoff's primary founder. Last, a private consulting company, Integrated Circuit Engineering (ICE), put together an annual list of the sales of all merchant semiconductor producers with sales exceeding a threshold for the years 1974 to 2002. A total of 101 of these firms entered by 1986. Klepper [2009] traced the backgrounds, years of entry and exit, and acquisitions of nearly all of these firms using the Silicon Valley genealogy, web searches, and other sources. This information was used in turn to identify the backgrounds of additional IC entrants, including additional spinoffs.[9]

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[8] For some entrants, it was difficult to tell from the description in the *Standard Catalog* whether a featured person that worked at a prior automobile firm was a founder or key employee. Such firms, which were typically shorter lived, were generally classified as spinoffs. In a few cases individuals were involved in rapid succession in two spinoffs after longer employment in a single firm. In these cases, the longer-term employer was designated as the parent of both spinoffs (see Klepper [2007]).

[9] A few of the firms classified as spinoffs were financed by non-semiconductor firms (and sometimes organized as subsidiaries) or involved a reconstitution of an existing semiconductor firm in which the new "founders" were given an ownership interest. Fairchild, for example, was financed by and later became a subsidiary of Fairchild Camera and Instrument, a Long Island military contractor. National Semiconductor, which was located in Connecticut, was an example of a reconstituted firm that brought in Charles Sporck, the head of manufacturing at Fairchild, to reconstitute its efforts in Silicon Valley, effectively giving birth to a new firm. Following general practice, National was classified as a spinoff of Fairchild. One other firm,

Finally, information concerning the output and sales of the leading automobile and semiconductor firms was compiled from various sources. In automobiles, Bailey [1971] listed the annual output of the leading makes of automobiles from 1896 onward (after the earliest years, between 15 and 20 leading makes are listed), which was used to identify the leading automobile producers each year. *Thomas' Register of American Manufacturers*, an annual marketing directory first published in 1905, listed the producers of numerous manufactured products and reported each firm's capitalization in one of eleven categories, with the top category $1,000,000 and above.[10] The list of automobile producers was matched to Smith's list, and for spinoff and startup entrants the first listing of the firm's capitalization in *Thomas'* was used to determine its size at entry.[11] For semiconductors, the ICE listings were used to compute the market shares of the largest semiconductor producers (i.e., the firms on the lists) from 1974 to 1986.

III. Evolution of the Automobile and Semiconductor Industries

Following Klepper [2009], the broad outlines of the evolution of the automobile industry around Detroit and the semiconductor industry around Silicon Valley are described.

A. Automobiles

The annual number of automobile entrants, exits, and producers from 1895 to 1966 based on Smith [1968] is plotted in Figure 1. Entry into the industry was concentrated in its first 15 years. From 1895 to 1900, entry averaged 11.5 firms per year, which increased to 36.8 firms per year from 1901 to 1905 and then peaked at 82 firms in 1907. Entry remained high for the next three years and then dropped to approximately 15 firms per year from 1911-1922, after which only 15 firms entered through 1966. The

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MOS Technology, had a similar history to National and was classified as a spinoff of Motorola (see Klepper [2009]).

[10] One of the eleven categories was reserved for firms whose capitalization could not be determined, which were generally shorter-lived firms.

[11] This matching was complicated by the fact that no information was available before 1905 and *Thomas'* was not published for a few of the years before 1921. A correspondence was developed between the entry year in Smith [1968] and the first volume in *Thomas'* in which entrants generally appeared. A firm's entry size was recorded based on its capitalization in the corresponding *Thomas'* volume or the next one if it was not listed in the "expected" volume; otherwise the firm's capitalization was classified as unknown.

number of firms peaked at 272 in 1909. Subsequently it fell sharply, dropping to 9 by 1941 despite enormous growth in the industry's output.

Table 1 lists the leading eight states in terms of the total number of automobile entrants. While Michigan was the leading state, entrants were dispersed throughout the Northeast and Midwest. Figure 2 plots the annual percentage of firms located in the Detroit area[12] through 1941. None of the initial sixty-nine entrants from 1895 to 1900 entered in the Detroit area, with the first entrant in the Detroit area, Olds Motor Works, entering in 1901. Subsequently the percentage of producers in the Detroit area rose steadily, reaching around 25% in the mid 1920s and then over 50% by 1941.

The share of automobile firms in the Detroit area in the early years greatly understates the clustering of the automobile industry there. Table 2, which lists the market shares of the leading automobile producers every five years from 1900 to 1925,[13] indicates that by 1910 seven of the top 10 producers of automobiles were located in the Detroit area, with Detroit area firms having a combined market share of 65%. This share rose further after 1910 as the leading Detroit area firms, led by Ford, General Motors, and later Chrysler, increased their dominance of the industry.

Much of the growth of the industry around Detroit was attributable to spinoffs. Olds Motor Works, which was a successful engine producer, was the first great firm in the industry and in its short life as an independent firm (it was acquired by General Motors in 1908) it spawned the most spinoffs of any firm in the industry,[14] including three of the industry's leaders. Nearly all the rest of the later entrants in the Detroit area that became leaders of the industry (see Table 2) were spinoffs. Table 1, which breaks down the entrants in the leading states into diversifiers, spinoffs, and startups, illustrates the importance of spinoffs in Michigan versus the other leading states. Michigan had a total of 59 spinoffs that constituted 44% of all of its entrants. In contrast, the next closest

[12] Firms were classified in the Detroit area if they located in Michigan within 100 miles of Detroit. The 100-mile distance was chosen to reflect movement and branching of firms within approximately a 100-mile distance of Detroit. Eleven of the 725 entrants moved in or out of the 100-mile region, and they were classified as in the region if they spent the majority of their years producing there.
[13] This was compiled from annual data reported in Bailey [1971] on the output of the leading makes of automobiles and data from the FTC [1939] on the total annual production of automobiles.
[14] General Motors and its constituents had as many spinoffs over a longer period.

states in terms of number of spinoffs were Ohio and Indiana with 16 each, which constituted 18% and 23% of their entrants respectively.

B. Semiconductors

The transistor was invented in 1947 by three Bell Labs (AT&T) scientists and effectively started the semiconductor industry. Under antitrust pressure, AT&T liberally disseminated its know-how and licensed its transistor patents and agreed to produce transistors only for its own use and the government market. Numerous firms entered into the production of transistors, as reflected in Figure 3, which presents the annual number of transistor entrants, exits, and producers from 1949 to 1987 based on the *EBG*. After the first few years, entry was fairly steady, averaging 11 firms per year from 1953-1973, and then it dropped to 7.8 firms per year from 1974-1987. The number of producers grew steadily to 90 by 1975 and then leveled off.

Figure 4 reports the fraction of transistor producers in four consolidated metropolitan statistical areas: Boston, Los Angeles, New York, and San Francisco, where the latter region is primarily composed of Silicon Valley firms (and hereafter is referred to as the Silicon Valley area). Producers concentrated early around the first three cities, with New York accounting for around 40% of the producers and Boston and LA around 15% by the latter half of the 1950s. Silicon Valley had no producers before 1955 and no more than 8% of the producers through 1960.

The first notable semiconductor producer in Silicon Valley was Fairchild Semiconductor, which entered in 1957. Along with Texas Instruments, it pioneered the silicon transistor and then the integrated circuit (IC), which was first commercially produced in 1961 and eventually took over much of the industry. Figure 5 presents the annual number of IC entrants, exits, and producers from 1965 to 1987 based on the *EBG*. From 1965 to 1973 entry averaged 39.7 firms per year and the number of producers grew to 154.[15] Subsequently entry dropped to an average of 20.9 firms per year through 1987 and the number of firms leveled off until it grew again after 1980, reaching a high of 210 in 1987. As reflected in Figure 6, which reports the share of IC producers in the New

[15] The sharp drop in the number of firms in 1970 corresponds to a change in the categories of ICs listed.

York, Los Angeles, Boston, and San Francisco areas, at first IC producers were concentrated in New York, Los Angeles, and Boston, each of which contained around 20% of the producers. Subsequently the percentage of producers in the Silicon Valley area steadily rose and by 1979 Silicon Valley was the leading area with around 20% of the IC producers, which increased further to over 23% by 1987. Figure 4 indicates that the share of transistor producers in the Silicon Valley area also grew after the advent of ICs, largely driven by the co-production of transistors and ICs by IC entrants.

Similar to Detroit, the share of transistor and IC firms in Silicon Valley greatly understates the clustering of the semiconductor industry there. Table 3 lists the periodic market shares of the leading semiconductor producers from 1957 to 1990.[16] By 1975 five of the top 10 semiconductor producers were located in Silicon Valley and collectively Silicon Valley firms accounted for 43% of the output of the industry, which increased to 48% five years later. Much of this growth was driven by Fairchild Semiconductor, through its own growth but even more importantly as the source of many of the subsequent leaders of the industry. Among the other four leading Silicon Valley firms in 1975, three were spinoffs from Fairchild and the fourth was a second generation descendant of Fairchild.

Fairchild was responsible for an extraordinary number of spinoffs, as will be discussed further below. It is instructive to consider the backgrounds of IC entrants in the different regions in the U.S. to understand the effect spinoffs had on Silicon Valley. In Table 4, IC entrants in New York, Los Angeles, Boston, San Francisco, and the rest of the U.S. are broken into five mutually exclusive categories according to whether they produced transistors, semiconductor diodes, active modules, or other electronics producers prior to ICs, with the remainder classified as "other firms."[17] Table 4 conveys a clear message: 80% of the IC entrants in the Silicon Valley area were not prior

[16] This was compiled from market share data reported in Tilton [1971, p. 66] for the years 1957, 1960, 1963, and 1966 and the ICE sales data for subsequent years.

[17] IC producers were designated as producing other products before ICs if they produced them before 1961, when the first IC was developed, or at least five years before they first produced ICs. The five-year rule was adopted to exclude IC entrants that entered with the intent of being an IC producer but produced other, less complex electronics products before they were ready to produce ICs. The closest product to ICs in terms of technology and market was the transistor, followed by semiconductor diodes, active modules, and

producers of transistors, diodes, active modules, or other electronics products versus 57% of the IC entrants in New York, 61% in Boston, 61% in LA, and 56% elsewhere. This reflects both the paucity of prior electronics producers in Silicon Valley before the advent of ICs and also the richness of the spinoff process there, as reflected in the Silicon Valley genealogy.

IV. Theory

The brief accounts of the evolution of the automobile and semiconductor industries indicate that the composition of entrants varied greatly across regions, with spinoffs playing a key role in the clustering of both industries. In this section a few key ideas regarding organizational competence based on a model of industry evolution in Klepper [2008] are laid out and used to explain prominent shared features of the Detroit and Silicon Valley clusters. The ideas are also used to derive various predictions that will serve as a basis for testing the theory.[18]

A key component of the theory is that firms differ innately in terms of their competence.[19] For simplicity, firms are assumed to come in two types, high (H) and low (L) competence. High competence firms are assumed to be larger and earn greater profits than low competence firms, *ceteris paribus*.

A firm's competence is assumed to be based on its pre-entry experience. Three types of entrants into a new industry are distinguished: diversifiers from other industries, spinoffs from incumbent producers in the new industry, and (other) startups. Consider first diversifiers. They have experience in another industry to exploit in the new industry. It is assumed that for a diversifier to be an H firm in a new industry it must be an H firm in its own industry. This is only a necessary condition, though, as being an H firm in the new industry depends on the firm's ability to transfer its experience into the new industry. Let p_d denote the probability that an H firm in another industry will be an H firm in a new

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then other electronics products, and prior producers were classified into (only) one of the four product categories based on this hierarchy.

[18] Buenstorf and Klepper [2009] used a similar approach to analyze the historical clustering of the U.S. tire industry.

[19] In high-tech industries like semiconductors and automobiles, competence would centrally involve a firm's ability to manage technological change.

industry. It is assumed that the more relevant a diversifier's industry to the new industry, the greater the value of p_d.

Spinoffs can exploit knowledge about the new industry that their founders gained while working in the industry at their "parent" firm. Spinoffs are typically formed by high level employees. For simplicity, it is assumed that every firm has the same number of such employees that can found spinoffs and each has the same probability of leaving to form a spinoff in any given period. Various theories of spinoffs predict that more competent firms spawn better-performing spinoffs (Franco and Filson [2006], Cassiman and Ueda [2006], Klepper and Thompson [2009]), which is supported by studies of spinoffs in a number of industries (Agarwal et al. [2004], Franco and Filson [2006], Klepper [2007], von Rhein [2008], Buenstorf and Klepper [2009]). Accordingly, it is assumed that for a spinoff to be an *H* firm, its parent must be an *H* firm (in the new industry). This is only a necessary condition, though, as being high competence depends on the ability of the spinoff founder to exploit his or her experience at the parent firm. Let p_s denote the probability that a spinoff of an *H* incumbent firm will itself be an *H* firm in the new industry. Spinoffs are expected to inherit traits from their parents. Let s denote the probability that firms in the new industry have some particular trait. It is assumed that the probability of a spinoff having the trait is greater than s if its parent had the trait (when the spinoff was founded) and less than s otherwise.

The last group of entrants, startups, is composed of new firms founded by individuals without experience in the new industry. They are all assumed to be *L* firms in the new industry, reflecting their lack of organizational and industry experience.

Entrants have a home region. For diversifiers this is where they produced in their industry, for spinoffs it is where their founders worked (i.e., where their parent firm was located), and for startups it is where their founders previously worked and/or resided. It is assumed that entrants have valuable economic and social knowledge about their home region. For simplicity, it is assumed that all entrants locate in their home region to exploit this knowledge. Otherwise the location of firms has no effect on their performance—for example, a firm's profitability is not affected by the number or market share of firms in its home region.

At the time of entry, the profits of potential entrants with competence $k = L$ or H equal $\Pi_k + \varepsilon$, where ε is a idiosyncratic factor that is assumed to be a draw from a uniform distribution defined over the interval [-½,½], and Π_L and Π_H are normalized such that $-½ < \Pi_L < \Pi_H < ½$. Potential entrants enter if their profits are nonnegative. This implies that the probability of entry of potential entrants of type k is $\Pi_k + ½$ and the profits at entry of entrants of type k are uniformly distributed over the interval $[0, \Pi_k + ½]$. The former result implies:

Proposition 1: a) H firms in another industry are more likely than L firms in the same industry to enter a new industry; b) The more related an industry is to a new one (i.e., the larger p_d) then the greater the probability that firms in the industry enter the new industry, *ceteris paribus*; and c) H incumbent firms spawn a greater expected number of spinoffs than L incumbent firms in the new industry.

Proof: The probability that an H firm in another industry enters a new industry is $p_d(\Pi_H + ½) + (1-p_d)(\Pi_L + ½)$, which exceeds the probability that an L firm in the same industry enters the new industry, $(\Pi_L + ½)$ (part (a)). Since $p_d(\Pi_H + ½) + (1-p_d)(\Pi_L + ½)$ is an increasing function of p_d, the more related an industry is to a new industry then the greater the probability that H firms in the industry, and hence firms in the industry overall, enter the new industry (part (b)). Last, the probability of entry of a spinoff from an H incumbent is $p_s(\Pi_H + ½) + (1-p_s)(\Pi_L + ½)$, which is greater than the probability of entry of a spinoff from an L incumbent, $(\Pi_L + ½)$. Therefore, H firms spawn a greater expected number of spinoffs than L firms (part (c)).

The output of a firm is assumed to be an increasing function of its competence, which is directly related to its profit. Accordingly, the output of firms is assumed to be an increasing function $q(.)$ of their profits, with $q(0) > 0$ and $q' > 0$. Hence at the time of entry, the output of entrants of type k is uniformly distributed over the interval $[q(0), q(\Pi_k + ½)]$, which implies that the maximum and average entry size of H firms is greater than that of L firms. Therefore:

Proposition 2: The maximum and average entry size of spinoffs is greater than startups, and spinoffs of H incumbents enter at a greater maximum and average size than spinoffs of L incumbents.

Proof: Some spinoffs are H firms whereas all startups are L firms, hence spinoffs enter at a greater maximum and average size than startups. Similarly, only spinoffs of H incumbents can themselves be H firms, hence the maximum and average entry size of spinoffs of H incumbents is greater than that of spinoffs of L incumbents.

To explain differences in the length of firm survival in the new industry, a mechanism to induce exit is needed. It is assumed that in every period t, firms experience a permanent additive shock μ_t to their profits and exit if their profits fall below 0. For simplicity, it is assumed that μ_t can take on three possible values, $d>0$, $-d$, or 0, with probabilities p, p, and $(1 - 2p)$ respectively, so that $E(\mu_t) = 0$.

Consider the hazard of exit t periods after entry of firms of type $k = L$ or H, where it is assumed that $dt < \Pi_L + ½$. The only firms at risk of exit are those that had profits at the time of entry less than or equal to dt and that are still in the industry. For simplicity, let the fraction of these firms of type k that survive to the beginning of period t equal its expected value of α_t, which is the same for firms of either type. Analogously, let the fraction of these survivors with profits less than or equal to d equal its expected value of β_t, which is also the same for firms of either type. Then t periods after entry, the hazard of exit of firms of type k equals $p\alpha_t\beta_t td/[\Pi_k + ½ - (1 - \alpha_t)td]$, which implies that the hazard of exit is greater for L than H firms. Intuitively, in every period a greater fraction of L than H firms have profits that put them at risk of exit. Therefore:

Proposition 3: Among contemporaneous entrants, on average the hazard of exit in each period is lower for: a) diversifiers and spinoffs than startups; b) diversifiers that are H versus L firms in their own industry; c) diversifiers from more related industries (i.e., for which p_d is greater); and d) spinoffs from H versus L incumbents.

Proof: Some fraction of diversifiers and spinoffs are H firms whereas all startups are L firms, hence on average diversifiers and spinoffs have lower hazards of exit than startups (part (a)). Only diversifiers that are H firms in their industry can be H firms in the new industry, hence on average they have lower hazards of exit than diversifiers that are L firms in their industry (part (b)). The greater p_d then the greater the fraction of diversifiers from a related industry that are H firms, hence the lower their hazard of exit (part (c)). Only spinoffs from H incumbents can be H firms, hence on average spinoffs from H incumbents have lower hazards of exit than spinoffs of L incumbents (part (d)).

The theory can now be used to provide a simple account of the clustering that characterized Detroit and Silicon Valley. These regions shared five notable features:

1) Neither region had many entrants at first.
2) Both had an initial entrant that became an early leader of the industry—Olds Motor Works, which produced engines before automobiles, and Fairchild Semiconductor, which produced transistors before ICs.
3) Both Olds and Fairchild were the source of many spinoffs, a number of which became leaders of the industry, and as will be seen a number of their spinoffs in turn were fertile sources of spinoffs, leading both regions to have a disproportionate number of spinoff entrants.
4) Both regions had firms of above average size.
5) Over time, the share of the industry's firms and output accounted for by both regions increased.

To explain these five patterns, a stylized account based on the theory is employed. Let there be $j = 1, 2, \ldots, J$ regions, where region 1 is Detroit and Silicon Valley. Suppose for simplicity there is only one industry that supplies diversifying entrants to the new industry, and let D_{kj} denote the number of firms of type $k = L$ or H in region j in that industry. Let A_j denote the number of potential startup entrants in region j based on the level of economic activity there. Suppose p_d is very low and only one diversifier attains high competence in the new industry, and this firm does not enter the new industry when it begins. Suppose $D_{H1} \approx 0$ but by chance this one firm enters in region 1. Further, suppose $D_{L1} = A_1 = 0$, and no other diversifier or startup enters in region 1, but $D_{Lj} > 0$, $D_{Hj} > 0$, and $A_j > 0$ for $j \neq 1$ and diversifiers and startups (all of which are low competence) enter in other regions. Last, suppose that high competence is such an advantage that after a certain point in the industry's evolution only H firms survive.

Under these assumptions, the industry evolves as follows. At first, there are no firms in region 1 (feature (1)). The first H firm in the industry locates in region 1 (feature (2)). Subsequently, it spawns both H and L spinoffs in region 1, and the H spinoffs in turn spawn H and L spinoffs. In other regions, entrants are a mix of diversifiers, spinoffs, and startups, so the fraction of entrants that are spinoffs is greater in region 1 than elsewhere (feature (3)). All firms in the other regions are L firms, so the firms in region 1 on average are larger than the firms in other regions (feature (4)). Last, over time the percentage of firms and industry output accounted for by the firms in region 1 rises and the industry clusters there (feature (5)).

This is of course an exaggerated account to illustrate simply how the theory can explain the most notable aspects of the evolution of the Detroit and Silicon Valley clusters. The three propositions summarize more generally patterns that should be expected if the theory underlying the stylized account is correct. When these propositions are applied to the explanation for the Detroit and Silicon Valley clusters, the following two predictions should also hold:

1) The size distribution of entrants in Detroit and Silicon Valley should dominate the size distribution of entrants in other regions, with this holding only for spinoffs, and more narrowly only for the spinoffs of the leading firms.
2) In each period, the firms in Detroit and Silicon Valley should have lower hazards of exit than firms elsewhere, but this will hold only for spinoffs, and more narrowly only for the spinoffs of the leading firms that enter at the largest sizes.

Alternatively, suppose that being located in a cluster provides firms with an advantage that increases their profits, as featured in modern theories of geography (cf. Krugman [1991], Krugman and Venables [1995], Belleflamme, Picard, and Thisse [2000], Fujita and Thisse [2002], Duranton and Puga [2004]). The implications of this in the context of the simple framework laid out above are straightforward. Let M denote the firm's additional profits if it is located in a cluster, where it is assumed that $-½ < \Pi_L < \Pi_H < ½ - M$. Then for a firm of type $k = L$ or H, the probability of entry would equal $\Pi_k + ½ + M$ if the firm was located in a cluster versus $\Pi_k + ½$ otherwise. Hence all else equal, entry would be greater in clusters for all types of firms. Furthermore, the maximum profits of firms of type k would be $\Pi_k + ½ + M$ if they were located in a cluster and $\Pi_k + ½$ otherwise, so firms of all types in clusters would have lower hazards of exit. In contrast, the proposed theory implies that only spinoffs and not diversifiers or startups would have higher entry rates and lower hazards of exit if they were located in a cluster, and this would only be because on average they had more competent parents.

V. Automobiles

The predictions of the theory that can be tested are dictated by the data that were collected. A total of 725 firms entered the automobile industry between 1895 and 1966, with 714 entering by 1925. All tests are confined to these 714 firms. They are composed of 224 diversifiers, 142 spinoffs, and 348 startups, where the top three products produced by the diversifiers prior to automobiles are carriages & wagons (65 firms), bicycles (26 firms), and engines (22 firms). The following predictions of the theory can be tested using the data that were collected for the automobile entrants:

1) The leading firms, which are disproportionately concentrated in the Detroit area, spawn spinoffs at the highest rate;
2) The fraction of entrants that are spinoffs is greater for entrants in the Detroit area than elsewhere, with the spinoffs in the Detroit area having parents located there;
3) After controlling for the quality of firms, the rate at which firms spawn spinoffs is no different in Detroit than elsewhere:
4) The distribution of entry sizes for spinoffs in the Detroit area dominates the distribution for spinoffs outside of the Detroit area and for startups, whether in or outside the Detroit area. Furthermore, this dominance should be confined to the spinoffs in the Detroit area that descended from the leading firms.
5) Diversifiers and spinoffs survive longer than startups, and if carriages & wagons, bicycles, and engines are considered the three most related industries to automobiles (and thus have the highest value of p_d), then diversifiers from the carriage & wagon, bicycle, and engine industries survive longer than other diversifiers.
6) Firms in the Detroit area survive longer than firms elsewhere, with the longer survival confined to spinoffs in the Detroit area and in particular to the spinoffs descended from the leading firms that entered at the largest sizes.

Consider first the predictions concerning spinoffs. Nearly all the spinoffs entered in the period 1899-1924. A total of 96 firms spawned one or more spinoffs in this period, with 68 spawning only one spinoff. There are too many parents to list them all, but following Klepper [2009] the 28 that spawned two or more spinoffs in 1899-1924 are listed in Table 5. For each firm, the total number of its spinoffs and the number that ever produced a leading automobile make (through 1924) are listed along with whether the firm itself ever produced a leading automobile make.[20] Consistent with the first prediction, the top five parents and seven of the top eight all produced leading automobile makes and the top seven parents were all located in the Detroit area.[21] Olds Motor Works was especially influential; not only did it have the most spinoffs along with Buick/GM (in a shorter time interval), but the top six parents after Olds were all related to Olds.[22] Consistent with the second prediction, spinoffs accounted for 48% of the 112 entrants in the Detroit area versus 15% of the entrants elsewhere. Spinoffs generally located close to their parents, as exemplified by the spinoffs in the Detroit area—49 of the 54 spinoffs in the Detroit area had parents located there and all but 10 of the 59 spinoffs with parents in the Detroit area located there.

Following Klepper [2007], a logit analysis of the rate at which automobile firms spawned spinoffs is used to formally analyze the spinoff process. Each firm's lifetime as an automobile producer is broken into annual intervals starting with the year before production began or 1899, whichever is later, and continuing five years after production ceased (through 1924).[23] All firm-years are pooled. The dependent variable equals 1 in a year in which a firm has one or more spinoffs[24] and 0 otherwise. To test whether better firms had higher spinoff rates, two explanatory variables are constructed: a 1-0 dummy equal to 1 if the firm had produced a leading automobile make in the current or preceding

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[20] No spinoff occurred in 1925, so the period examined is ended at 1924.
[21] See Klepper [2007] for a genealogical tree encompassing the spinoffs of all of these firms.
[22] Its two main subcontractors, Leland and Faulconer and the Dodge Brothers, played a key role in the success of Cadillac and Ford Motor Co., and another one of Olds' subcontractors, Benjamin Briscoe, initially financed Buick (see Klepper [2007]). Northern was a spinoff of Olds that was co-founded by Jonathan Maxwell, who also co-founded Maxwell-Briscoe, making Olds a secondary parent of Maxwell-Briscoe. Last, Hupp was founded by Robert Hupp of Ford, who had initially worked for Olds before moving to Ford. A number of other well known individuals in the industry also worked for Olds during its brief life as an independent producer before being acquired by General Motors. All told, Olds Motor Works had a great impact on the industry, leading one observer of the industry to describe its leader, Ransom Olds, as the "schoolmaster of motordom." (Doolittle [1916, p. 44])
[23] A number of spinoffs were founded after the parent firm exited (generally within five years of its exit date) and two were formed before its parent began production, which is the basis for the interval considered.
[24] There were 126 firm-years with one or more spinoffs, including six with two spinoffs and one with three spinoffs. An ordered logit was estimated to accommodate the observations with multiple spinoffs, which

five years, and a 1-0 dummy equal to 1 if the firm had produced the number one or two make in the current or preceding five years.[25] It has been found that firm age and whether a firm was recently acquired affect the firm spinoff rate (Klepper and Sleeper [2005]). To test the effect of age, the number of years a firm produced automobiles and its square were included as an explanatory variables (for years after a firm exited, both are based on the total number of years of production). To test whether spinoff rates are higher around the time of acquisitions, two 1-0 dummies for acquisitions by automobile and non-automobile firms are included based on data in Smith [1968] on ownership changes. Each equals 1 in the year a firm was acquired and in the year before and two years after the acquisition.[26] A 1-0 dummy variable equal to 1 for years after a firm exited is included to test whether the spinoff rate declined after exit, as might be expected. Year dummies are included to reflect variations in entry conditions over time. Last, a 1-0 dummy equal to one for firms located in the Detroit area is included to test if clustering affected the firm spinoff rate.

The coefficient estimates of all but the year dummies are reported in Table 6. Consistent with the first prediction and the patterns reflected in Table 5, the coefficient estimates of the two variables pertaining to producing a leading automobile make are both positive and significant at the .01 level (for any leading make) and .05 level (for the top two makes), indicating that firms producing the top two makes had the highest spinoff rate (reflected in the sum of the two coefficient estimates) followed by firms producing any leading make. The coefficient estimates of age and age squared are positive and negative respectively with the former significant at the .01 level and the latter falling just short of significance at the .10 level. They imply a maximum spinoff rate at age 17.6, which is within the sample range. The probability of a spinoff is significantly greater around when firms were acquired by either auto or non-auto firms at the .05 and .01 levels respectively. Not surprisingly, the probability of a spinoff is significantly lower, at the .10 level, in the five years after a firm has exited. Last, the

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had little effect on the estimates. Eight spinoffs were founded more than five years after the exit of its parent and thus were not included in the analysis.

[25] The number of top makes to include in the latter variable was chosen based on fit.

[26] Forty-six firms exited by being acquired by another automobile firm and there were 120 acquisitions by non-automobile firms.

coefficient estimate of the Detroit dummy is positive and significant at the .01 level and implies (roughly) a 2.77 greater spinoff rate for firms in the Detroit area.[27] This is inconsistent with the third prediction. It is consistent with clustering increasing firm profitability (as featured in modern theories of geography), although alternative explanations for this pattern are also considered later.

The fourth prediction can be tested using the information reported in Table 7 on the percentage of various startup and spinoff entrants that entered in each of the size categories in *Thomas' Register*, including a category "unknown," and an additional category, "unobserved," for entrants not found in *Thomas'*. These percentages are reported separately for startups in the Detroit area and elsewhere, spinoffs in the Detroit area and elsewhere, and spinoffs in the Detroit area broken down according to whether their parent produced a leading automobile make in the entry year of the spinoff or the preceding five years. Among the startups, 3.6% and 5.4% of the non-Detroit and Detroit startups respectively entered at the highest three size categories. Similarly, 4.4% of the non-Detroit spinoffs entered in these three size categories. Consistent with the fourth prediction, a much higher percentage of the Detroit spinoffs, 17.3%, entered in these three top size categories, with a still greater 26.6% of the Detroit spinoffs with parents that ever produced a leading automobile make entering in these three size categories. Furthermore, the greater size of the spinoffs in the Detroit area is confined to the ones that descended from the leaders; the distribution of entry sizes for the other Detroit spinoffs is similar to the distributions for the non-Detroit spinoffs and the startups in the Detroit area and elsewhere. The comparison is similar if extended to the top five size categories.[28]

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[27] The coefficient estimate is the derivative with respect to being located in Detroit of the log of the odds of a firm spawning a spinoff relative to not spawning a spinoff. Therefore, $\exp\{1.02\} = 2.77$ quantifies how much greater the odds ratio is for firms in the Detroit area. Since the annual probability of spawning a spinoff is quite low, this translates roughly into Detroit firms having a 2.77 higher probability of spawning a spinoff than firms elsewhere.

[28] Assuming firms in the unknown and unobserved categories had initial capitalizations below \$300,000 (i.e., the top three size categories), Fisher's exact test was used to test whether the probability of entrants starting with a capitalization of \$300,000 or greater was larger for spinoffs in the Detroit area with a leading parent than the other Detroit spinoffs, the spinoffs not in the Detroit area, and the startups in the Detroit area and elsewhere. The two-tailed p-values for the respective comparisons are .061, .034, .001, and .0001.

The last two predictions are tested by estimating an annual hazard of exit model over the period 1895-1966. Klepper [2002, 2008] found that a Gompertz model fit the data well for the automobile industry:

$$h_{it} = \exp(\{\gamma_0 + \underline{\gamma}'\underline{z}_{it}\}age_{it})\exp(\beta_0 + \underline{\beta}'\underline{x}_{it}),$$

where $\underline{z}_{it}$ is a vector of variables that condition how the age of firm i in year t, age_{it}, affects the hazard, $\underline{x}_{it}$ is a vector of variables that affect the hazard proportionally at all ages, γ_0 and β_0 are constant terms, and $\underline{\gamma}$ and $\underline{\beta}$ are coefficient vectors. Following Klepper [2008], all variables are entered in the vector $\underline{x}_{it}$ to allow them to affect the hazard proportionally at all ages. Additionally, dummy variables for entry cohorts were entered in both $\underline{x}_{it}$ and $\underline{z}_{it}$, reflecting that their influence varied according to the age of firms.[29] Firms that exited by being acquired by another firm or that were still producing at the end of the data period in 1966 were treated as censored. All coefficient estimates are reported as hazard ratios, so that numbers below (above) one indicate a reduction (increase) in the hazard relative to the omitted group.

An initial version of the model was estimated with a single variable in $\underline{x}_{it}$, a 1-0 dummy equal to 1 for firms located in the Detroit area, to test if these firms survived longer, *ceteris paribus*. Consistent with the sixth prediction, the coefficient estimate of the Detroit dummy, which is reported in Table 8 under the column labeled Model 1, is less than one and significant at the .01 level, implying a 32% lower annual hazard for firms located in the Detroit area.[30]

Next dummies were introduced in $\underline{x}_{it}$ for diversifiers and spinoffs to test if they had lower hazards, and an additional dummy was added in $\underline{x}_{it}$ for diversifiers that previously produced carriages & wagons, bicycles, or engines to test if they had lower hazards than other diversifiers. The spinoff dummy is also interacted with the Detroit dummy to test if the lower hazard of the firms in the Detroit area was confined to the spinoffs located there. Following Klepper [2008], entrants were broken into three cohorts

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[29] This is consistent with the model of industry evolution developed in Klepper [2002].

[30] The Detroit dummy was arbitrarily divided into two dummies covering the periods 1895-1920 and 1921-1966 to test if the lower hazard of the Detroit firms was confined primarily to the earlier period, as might be expected if equilibrating forces diminished any advantage conferred by being located in the Detroit area. The coefficient estimates, with standard errors in parentheses, are respectively 0.72 (0.13)** and 0.56 (0.26)**, suggesting that if anything the opposite was true.

of roughly equal size: 1895-1904, 1905-1909, and 1910-1924, and dummies for the first two cohorts were included in both $\underline{x}_{it}$ and $\underline{z}_{it}$.[31]

The coefficient estimates for this model are reported in Table 8 under the column headed Model 2. All of the coefficient estimates conform with the predictions of the theory. The coefficient estimates of the diversifier and spinoff dummies are both less than one and significant at the .01 level and the coefficient estimate for the diversifiers from the carriage & wagon, bicycle, and engine industries is also less than one and significant at the .05 level. The estimates imply that diversifiers and spinoffs had 37% and 34% respectively lower annual hazards than the omitted group of startup entrants, and the annual hazards of the diversifiers were 30% lower still if they came from the carriage & wagon, bicycle, or engine industries. The coefficient estimate for the Detroit spinoffs is also less than one and significant at the .01 level, confirming the lower hazard of spinoffs located in the Detroit area. Consistent with the sixth prediction, the coefficient estimate of the Detroit dummy equals one and is insignificant, suggesting that it was only the spinoffs in the Detroit area and not the other firms located there that had lower hazards.[32] The coefficient estimates of the time of entry variables are less than one and significant (at the .01 and .05 levels) only in the interaction with age, implying that earlier entry lowered the hazard only at older ages.

Last, two 1-0 dummy variables for the spinoffs of leading firms that entered at the largest sizes are added as explanatory variables in $\underline{x}_{it}$ to test if the greater longevity of the Detroit spinoffs was confined to these firms. The first variable, denoted as Largest Top Spinoffs, equals 1 for the nine spinoffs that entered at the highest three size categories and had a parent that produced a leading automobile make in its entry year or the preceding five years. The second variable, denoted as Next Largest Top Spinoffs, equals 1 for the 18 spinoffs that entered in the next two highest size categories and had a parent that produced a leading automobile make in its entry year or the preceding five years and

[31] There are no a priori predictions about the functional form of the relationship between time of entry and the hazard. The cohort division is arbitrary but fits the data well. The estimates are robust to different cohort divisions.

[32] This was not due to the introduction of controls for the time of entry and firm backgrounds—when these variables were included without the dummy for the Detroit spinoffs, the coefficient estimate for the Detroit dummy hardly changed from Model 1.

the six spinoffs that entered at any of the five highest size categories and had a secondary parent that produced a leading make in its entry year or the preceding five years.

The estimates for this specification are reported in Table 8 under the column Model 3. The coefficient estimates for both variables are less than one and significant at the .01 and .05 levels respectively. The estimates imply an 87% lower annual hazard for spinoffs of leading firms that entered at the largest sizes and a 43% lower annual hazard for the other group of spinoffs of leading firms that entered at the larger sizes. More important, the coefficient estimate of the Detroit spinoff dummy rises and is closer to one and no longer significant, consistent with the sixth prediction of the theory.

VI. Semiconductor Industry

The semiconductor industry clustered in Silicon Valley after ICs were developed. Accordingly, the analysis focuses on entry into the production of ICs and the performance of IC entrants according to their heritage and location.

Data on the entry sizes of the IC entrants were not available, but otherwise the same tests could be done for semiconductors as automobiles, albeit less comprehensively given the limited number of IC entrants whose origins could be traced. Data were also collected on transistor, diode, and active module producers, which can be used to test how their experience in these industries prior to the advent of ICs influenced whether they entered ICs and how long they survived. The theory predicts that firms with greater pre-entry experience are more likely to enter and survive longer. Data were also collected on the type of IC produced at entry, which can be used to test the assumption that spinoffs inherit traits from their parents.

Consider first entry into ICs by transistor, diode, and active module producers. Based on the *EBG*, as of 1964 388 firms were producing these products. Of these, 28 subsequently entered ICs with less than five years of experience in their product and thus did not qualify as a diversifier based on the required five years of pre-entry experience (see footnote 17). Accordingly, these 28 firms were excluded from the analysis and a model of the hazard of entry into ICs from 1965 to 1987 was estimated for the other 360 firms,[33] with a Cox proportional hazard model used to obviate having to specify a functional form for the hazard.[34] Firms that never entered through 1987 are treated as censored. All coefficient estimates are reported in ratio form, so that estimates above one indicate variables that increased the hazard of entry and estimates below one indicate the opposite.

A series of models are estimated. The first model contains three 1-0 dummies for location in the three early electronics clusters of Boston, Los Angeles, and New York and a 1-0 dummy for location in Silicon Valley, with all other areas serving as the omitted category. The next model adds two 1-0 dummies for production of transistors and diodes, with producers of active modules the omitted group. The product most related to ICs was transistors, followed by diodes and active modules. Consequently, based on Proposition 1b, transistor producers are expected to be more likely to enter than diode producers, which in turn are expected to be more likely to enter than active module producers. Model 3 adds the years of production (of the respective product) through 1964 for producers of each of the three products and also a dummy for the leading transistor producers in 1957 and 1960 based on market share data for those years reported in Tilton [1971]. Assuming years of experience and being a larger transistor producer are proxies for competence, Proposition 1a implies that more experienced firms and larger transistor producers should have higher hazards of entry. Once the backgrounds of firms are controlled, the theory predicts that firms in clusters should be no more likely to enter than other firms. Alternatively, if clusters raise firm profitability then firms located in New York, which had the greatest number of transistor and diode producers in 1964, would be more likely to enter, followed by firms in Los Angeles, Boston, and Silicon Valley.

Table 9 reports coefficient estimates for the various models. In Model 1 with only the four regional dummies, Silicon Valley has the largest coefficient estimate, 2.05, but none of the coefficient estimates is significant. In Model 2, the coefficient estimates of the product dummies for transistor and diode producers are greater than one and significant at the .01 and .05 levels respectively. Consistent with the ordering of their relevance to ICs, transistor producers were more likely to enter than diode producers,

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[33] The estimates were similar when the model was estimated with all 388 firms.

which in turn were more likely to enter than (the omitted group of) active module producers. When years of experience for each product and the dummy for the leading transistor firms are added in Model 3, consistent with the theory the coefficients are all greater than one and significant at various levels. The coefficient estimates of the regional dummies are all insignificant, suggesting that being in a cluster did not increase the probability of entry, consistent with the theory.

Next the rate at which firms spawned spinoffs is analyzed. This was done for the firms on the ICE listings, which is the only group whose origins could be comprehensively traced. Table 10 lists for each firm the number of its spinoffs on the ICE listings. The column labeled # spinoffs adds for each firm the spinoffs that appeared on the Silicon Valley genealogy but not on the ICE listings, which provides a comprehensive estimate of the number of spinoffs for the Silicon Valley firms. Also reported is whether the firm reached the top 20 producers in sales in any of the ICE annual listings, the number of its spinoffs that ever attained this status, and the years the firm produced semiconductors.

Table 10 reflects the extraordinary influence of Fairchild on the spinoff process in Silicon Valley. It alone accounted for 14 of the 53 spinoffs that made it onto the ICE lists and 24 of the 91 total spinoffs when the other Silicon Valley spinoffs are added. Moreover, the next three Silicon Valley firms with the most spinoffs, Intel, National, and Signetics, are all spinoffs of Fairchild, and the next Silicon Valley firm, Intersil, was founded by one of the founders of Fairchild (after starting another firm first). Most of the other Silicon Valley firms are connected to Fairchild as well, either as a spinoff of Fairchild, a spinoff of one its spinoffs, or having a founder that at one point worked for Fairchild. The contrast between the number of firms in Silicon Valley with spinoffs, 22, and the number of firms elsewhere with spinoffs, 5, is also striking, as is the greater number of spinoffs of the most prolific spawners in Silicon Valley than elsewhere.

The top six Silicon Valley firms in Table 10 were all top 20 firms as were all the firms that had spinoffs outside of Silicon Valley. Thus, consistent with the theory, the leading firms in the industry, which were disproportionately concentrated in Silicon

[34] All tests failed to reject the null of proportionality

Valley, accounted for the greatest number of spinoffs. Also consistent with the theory, among the 92 firms on the ICE listings whose backgrounds could be traced, 53 of the 56 Silicon Valley firms (95%) were spinoffs versus only 15 of the other 36 firms (42%). Furthermore, spinoffs did not generally stray far from their roots, as exemplified by the Silicon Valley spinoffs—nearly every spinoff with a Silicon Valley parent located there and of the four with non-Silicon Valley parents, all four had Silicon Valley roots (three had a non-primary founder from a Silicon Valley firm and the founder of the fourth had previously worked at Fairchild).

Analogous to automobiles, a logit model of the spinoff process was estimated for the U.S. merchant ICE firms (96 in total) in which each firm's history was broken into annual intervals from its date of entry through its date of exit (or 1986 if it was still in the industry in 1986)[35] and all firm-years were pooled. The dependent variable is a 1-0 dummy equal to 1 for a firm with one or more spinoffs in a given year that made it onto the ICE listings.[36] A firm's competence is measured by its market share in the current year based on the ICE listings and Tilton [1971].[37] Similar to the logit model for automobiles, other independent variables include the number of years a firm produced semiconductors and the number of years squared, 1-0 dummies for firms acquired by semiconductor and non-semiconductor firms that take the value 1 in the year prior to and (up to) two years after the acquisition, year dummies, and a 1-0 dummy equal to 1 for firms located in Silicon Valley.

The coefficient estimates are reported in Table 11. As expected, the coefficient estimate of market share is positive and significant at the .01 level, confirming the impression from Table 10 that better firms spawned spinoffs at a greater rate. The

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[35] No firm had a spinoff before it began producing or after it exited, so the analysis is confined to the years each firm produced.

[36] There were 45 firm-years with one or more spinoffs, including six with two spinoffs and one with three spinoffs. An ordered logit was estimated to accommodate the observations with multiple spinoffs, which had little effect on the estimates.

[37] Some firms entered before the first ICE listing in 1974. Their 1974 ICE market share was used as their market share for the years 1969-1973. If their market share was reported for earlier years in Tilton [1971], it was used as their market share for years before 1969. If their market share was not listed in Tilton for the earlier years, they were assigned a market share of 1.0% or 0.5% if their 1974 ICE market share was less than 0.5%. For years after 1974, if a firm lacked market share data for the last year or two of its existence, it was assigned its last recorded market share for those years. In a few cases of firms with no market share

coefficient estimates of age and age squared are positive and negative respectively and both are significant at the .01 level. They imply that that the firm spinoff rate reached a maximum at age 15.1, which is within the sample range. The coefficients of both acquisition variables are positive but not significant, as might be expected given the small sample of acquired firms (eight by semiconductor firms, 16 by non-semiconductor firms). The coefficient estimate for being located in Silicon Valley is positive and significant at the .01 level and implies a (roughly) 5.16 times greater spinoff rate for firms in Silicon Valley.[38] This is not consistent with the theory but is consistent with clustering raising firm profitability, although as noted earlier alternative explanations for this pattern will be considered later. To test whether the estimates might have been unduly influenced by Fairchild, which was a clear outlier, the coefficients were re-estimated with all observations for Fairchild deleted. The sign and significance of all the coefficient estimates remained the same except for the Silicon Valley effect, which was significant at the .10 level and implied a 2.34 greater spinoff rate for Silicon Valley firms.

Monolithic ICs eventually dominated ICs and could be considered the technological frontier, but many firms continued over time to produce hybrid and film ICs. Fairchild developed and was the leading innovator of monolithic ICs. With nearly all Silicon Valley firms descended from Fairchild, if firms passed down traits to their spinoffs as conjectured in the theory, it would be expected that a larger fraction of IC entrants in Silicon Valley than elsewhere would produce monolithic ICs when they entered. Monolithic ICs were produced using the planar process that was employed to produce transistors, and thus it was also expected that prior transistor producers would be more likely to produce monolithic ICs at entry, perhaps followed by prior diode producers, prior active module producers, and prior electronics producers.[39] Later entrants were also expected to be more likely to produce monolithic ICs at entry as over time monolithic ICs increasingly took over the market.

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data for any year through 1986, they were assigned a market share equal to one half of the lowest market share of any firm on the ICE list in the respective year.

[38] The odds ratio of a spinoff is $\exp\{1.64\}= 5.16$ higher for firms in Silicon Valley, which translates into roughly a 5.16 higher spinoff rate given that the probability of not spawning a spinoff in any given year was close to 1.

[39] It was not clear where the "other firms" stood in this hierarchy, which would depend on the number of them that were spinoffs and the products produced by their parents.

To test these predictions, a logit model of whether IC entrants produced monolithic ICs at the time of entry is estimated. The dependent variable is a 1-0 dummy equal to 1 for firms that produced monolithic ICs at entry.[40] The explanatory variables include the four regional dummies, dummies for prior producers of transistors, diodes, active modules, and electronics products (the omitted category is "other firms"), and the year of entry. The coefficient estimates are reported in Table 12. The coefficient estimates for the four prior product dummies are ordered as expected, with the transistor and electronics coefficient estimates significantly different from the omitted category of "other firms." Later entrants were significantly more likely to produce monolithic ICs at entry, as expected. Last, the coefficient estimate of the Silicon Valley dummy is positive, significant at the .01 level, and large, consistent with the theory. Indeed, nearly every IC entrant in Silicon Valley—92%—produced a monolithic IC at entry, which is consistent with nearly all the Silicon Valley entrants being descended from Fairchild in one way or another, whereas only 47% of the entrants elsewhere produced a monolithic IC at entry.[41]

Last, the performance of IC entrants is considered. At first performance is measured by longevity (years of production of ICs). Successive Cox proportional annual hazard of exit models are estimated[42] over the period 1965-1987. The first model includes the four regional dummies, two dummies for entry between 1965-1969 and 1970-1974 to test if early entry was advantageous, and year dummies to accommodate a downward trend over time in the hazard.[43] The second model adds dummies for transistor, diode, active module, and electronics producers. Separate dummies are included for firms that

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[40] A firm was identified as producing a monolithic IC at entry only if it produced an IC in a category explicitly designated as monolithic.

[41] The estimates are also compatible with theories that feature geographically-mediated technological spillovers, which suggest that firms in clusters would be more likely to produce at the technological frontier. Curiously, though, among the other regions only the coefficient estimate for Los Angeles is notable and significant, suggesting that the Silicon Valley effect may be more due to heredity than clustering. Unfortunately, nearly all the entrants that could be verified as spinoffs based on the Silicon Valley genealogy and the tracing of the origins of the firms on the ICE listings produced a monolithic IC at entry (as did their parents), precluding a direct test of the heredity hypothesis. However, using data on the specific monolithic ICs (and also hybrid and film ICs) produced by spinoffs and their parents, Klepper, Kowalski, and Veloso [2009] find that spinoffs were significantly more likely to produce types of ICs their parents also produced, consistent with the heredity hypothesis.

[42] All tests failed to reject the null of proportionality

[43] With controls for year and age, the effect of time of entry is identified via functional form. While there is no a priori basis for the choice of entry cohorts, the inclusion of the time of entry variables has little effect on the other estimates.

produced these products by 1964, the year before ICs were first listed in the *EBG* (denoted by the prefix pre-), and after 1964 (denoted by the prefix post-) under the expectation that firms that did not directly enter into ICs might actually have been less competent. The next model adds the years of experience variables, entered separately for the pre- and post- diversifiers, and the dummy for being a leading transistor firm. The last model adds a 1-0 dummy equal to 1 for firms producing a monolithic IC at entry to test if being at the technological frontier at entry lowered the hazard. Also included is a 1-0 dummy equal to 1 for the 29 spinoffs on the ICE list whose parents' sales were among the top 20 firms on the ICE list in the spinoff's entry year or the preceding five years. This tests the prediction of the theory that firms with superior heritage have lower hazards.[44] Firms that were still producing at the end of the data period in 1987 were treated as censored.

The coefficient estimates of the models (except for the year dummies) are reported in Table 13. They are expressed in ratio form, so values below one indicate a lower hazard and above one a higher hazard. In all the models, earlier entry lowered the hazard, with the coefficient estimate for the first entry cohort always significant and the coefficient estimate for the second cohort significant in some of the models. In Model 1 without any firm controls, firms in Silicon Valley and Boston had significantly (at the .10 and .05 levels respectively) lower hazards. In Model 2 the pre- dummies are ordered as would be expected based on the theory (and the hazard of entry estimates). The coefficient estimates for the transistor and diode diversifiers are less than one and significant at the .01 and .10 levels respectively, signifying a lower hazard than the omitted group of other entrants. The coefficient estimate of the active module dummy equals 0.99 and the coefficient estimate for the electronics dummy is greater than one and significant at the .10 level, signifying a greater hazard than the omitted group of other entrants. In contrast, none of the coefficient estimates for the post- dummies is

[44] Parental heritage could only be comprehensively measured for firms on the ICE listings, which are by definition larger firms. To the extent these were the spinoffs that entered at the largest sizes, this is the appropriate variable to test the theory. Otherwise, the coefficient estimate will be biased downward to reflect a lower hazard of exit assuming larger firms survive longer, as is commonly found. Even if it is biased, though, it should be comparably biased for firms in all regions, and so it should still be possible to test if any greater longevity of firms in clusters is attributable to their heritage.

significant and the transistor coefficient estimate, which was significantly less than one for the pre- dummy, is now considerably greater than one. This is consistent with firms that choose to produce another electronics product before ICs not being more competent than those that directly entered ICs.

In Model 3, the coefficient estimates for all the years of experience variables are close to one and insignificant, while the dummy for the leading transistor firms is well below one, as might be expected, but is not significant. Except for electronics diversifiers, the pre- and post- samples of diversifiers are quite small, and it may be that less experienced diversifiers that entered ICs had other, unobserved attributes that compensated for their lack of experience, causing the coefficient estimates to be biased toward one. In Model 4, the years of experience variables are dropped but the dummy for the leading transistor firms is retained to facilitate comparison with later results (the results are insensitive to its inclusion). The coefficient estimate of producing a monolithic IC at entry is close to one and is not significant. In contrast, the coefficient estimate for the dummy for spinoffs of top 20 parents is .16 and significant at the .01 level, indicating that these firms had an 84% lower hazard than other IC entrants. More important, consistent with the theory the coefficient estimate for the Silicon Valley dummy rises to nearly one, reflecting the greater percentage of entrants descended from the leading firms in Silicon Valley than elsewhere (22 in Silicon Valley versus seven in all other regions). The coefficient estimate for the Boston region is less than one and significant (at the .10 level), as in Model 1, while the coefficient estimates for the other two regions are close to one and not significant.

The data on IC production span only 23 years, and longevity over such a period may have its limits as a performance measure. To probe the robustness of the estimates to the measure of performance, alternative measures were created based on the ICE sales data. Logit analyzes were estimated for whether firms ever attained the ten largest in any year, the 20 largest in any year, or simply were large enough to be on the ICE list in any year (through 2002). They all yielded similar estimates, and for brevity the estimates for the logit of attaining the top 20 producers are presented. The models estimated were similar to those for the hazard except the year dummies were not relevant and time of entry was entered as a continuous measure (year of entry) under the expectation that the later a firm entered then the less time it would have to attain the top 20 producers. The years of experience variables were also tried but had little predictive power and these results are not reported. Coefficient estimates that were not identified because they were perfect predictors of failure also could not be reported.

The coefficient estimates are reported in Table 14. One difference from the hazard of exit estimates is that in Model 1 without firm controls, the Silicon Valley effect is much more pronounced and significant at the .01 level. This reflects the disproportionate number of Silicon Valley firms that became leaders of the industry (20 versus 15 in all other areas). This persists in Model 2 with the inclusion of the pre- and post- dummies and leading transistor firms for the diversifiers. Another difference from the hazard of exit estimates is that producing a monolithic IC at entry has a strong effect on performance, reflecting the fact that every firm that got into the top 20 produced a monolithic IC at entry. Consequently, no coefficient can be estimated for this variable, but it can be entered as a control in Model 3, which effectively pares down the sample to the 329 firms that produced a monolithic IC at entry. The coefficient estimate for the Silicon Valley dummy is about 30% lower than in Model 2, reflecting the much greater fraction of entrants in Silicon Valley that produced a monolithic IC at entry, but it is still sizable and significant at the .01 level. When the dummy for being a spinoff of a top 20 parent is included in Model 4, it has a large, positive, and significant coefficient estimate and the coefficient estimate for Silicon Valley declines by approximately 50% and becomes insignificant. Consistent with the theory, once being at the technological frontier at entry is controlled, the greater likelihood of Silicon Valley firms reaching the top echelons of the industry is largely confined to the Silicon firms that were spinoffs of the leading firms (and attained the ICE listing).

In light of the relationship between producing a monolithic IC at entry and the probability of making it into the top rank of firms, a further analysis was done of the probability of producing a monolithic IC in a later year for those 294 firms that did not enter producing a monolithic IC. Of particular interest was whether this was more likely for firms located in clusters, reflecting some kind of technological spillover (that is not captured in the proposed theory). A Cox proportional hazards model of producing a monolithic IC in a later year after entry was estimated, with the regional and technological dummies included as explanatory variables. The only coefficient estimate that was significant was for prior transistor production. Furthermore, only 13% of the firms that entered not producing a monolithic IC ever produced a monolithic IC later. This is consistent with heritage rather than location being the primary determinant of whether a firm ever reached the technological frontier.

VII. Discussion

The parallels between the Silicon Valley and Detroit clusters are striking. In both industries, no firms were initially located in either Silicon Valley or Detroit, but then an outstanding innovative firm entered in both regions. In both instances, this firm contributed, through spinoffs and in Olds Motor Works' case subcontracting as well, to the creation of many other leading firms nearby. Once the spinoff process got going in both regions, it operated much more intensively than elsewhere, contributing to a disproportionate number of spinoff entrants in both regions. Spinoffs of leading firms performed especially well, and with spinoffs not straying far from their geographic roots, this led to a buildup of successful firms in Detroit and Silicon Valley. Indeed, firms in both regions were on average superior performers, but the superior performance was largely restricted to the spinoffs located there that were descended from the leading firms. Superior spinoffs in both industries were distinguished at birth, as reflected in their initial capitalization in automobiles and their propensity to produce at the technological frontier in semiconductors. Consistent with a broader process of organizational reproduction and heredity, better firms not only spawned more and better spinoffs but firms in more closely related industries were more likely to diversify into both industries and perform better than other entrants.

While organizational reproduction and heredity seem to have had a major influence on the emergence and growth of both clusters, it is less clear whether traditional agglomeration economies related to labor pooling, proximity to suppliers, and localized knowledge spillovers played a similar role. While the analysis was not directed toward evaluating the effects of agglomeration economies on the evolution of the two clusters, two observations seem pertinent. The superior entrants in the clusters were largely indigenous entrants and their superiority appears to have been based on innate characteristics they possessed at the time of entry, suggesting that agglomeration economies did not pull entrants to the clusters nor nurture their superiority. Alternatively, agglomeration economies might have fueled entry in the clusters by enhancing the profitability and hence probability of entry of indigenous potential entrants (Rosenthal and Strange [2003]), which could explain why the firm spinoff rate was so much higher in the clusters even after controlling for various factors. But if agglomeration economies were strongly at work it might have been expected that all kinds of firms would have been superior performers in the clusters, yet the superiority was largely restricted to spinoffs and in particular spinoffs descended from the leaders that entered at the largest sizes.[45] Perhaps some kind of equilibrating process, such as the bidding up of wages and prices in the clusters, offset the benefits of agglomeration economies and limited the performance of non-spinoff entrants in the clusters. Clearly, the theory sketched out in the paper is not adequate to analyze such a possibility. But if such a process was operative it would have to be explained why it did not compete away the advantages realized by the spinoffs in the clusters.

Numerous questions are raised by the role of spinoffs and more broadly organizational reproduction and heredity in the growth of the two clusters. For one, why did the clusters form in Detroit and Silicon Valley? Various attempts have been made to identify conditions that in retrospect favored the development of each industry in its cluster (cf. Tsai [1997], Sturgeon [2000]). But firms did not enter in either Detroit or Silicon Valley early on, suggesting that neither region was a likely place for their industries to cluster. Furthermore, nearly all the successful entrants could be traced back in one way or another to Olds Motor Works and Fairchild. Thus, it would seem to be the chance entry there of these two firms that was the key impetus for the two clusters.

But that only seems part of the story, and perhaps even a minor part judging from numerous regions that are blessed by an early innovator that never develop into an outstanding industry cluster. Indeed, one does not need to go far to find such an example—Texas Instruments (TI) and Dallas, TX in the semiconductor industry. TI

[45] The evidence is more discriminating for automobiles whereas in semiconductors there were not many non-spinoff IC entrants in Silicon Valley to compare to the spinoffs and data on firm origins were available only for a subset of the IC entrants.

pioneered the silicon transistor, with Fairchild close behind. TI and Fairchild were credited with co-inventing the integrated circuit and both were among the first producers of ICs. TI was continually at the forefront of the industry and its market share was consistently greater than Fairchild's. Yet as reflected in Table 10, Fairchild had many more spinoffs than TI and many more that attained the ranks of the industry's leaders, which was instrumental to the concentration of the industry in Silicon Valley rather than Dallas, TI's base location. Why? Did Fairchild have a uniquely entrepreneurial culture that encouraged the formation of spinoffs (Gompers, Lerner and Scharfstein [2005])? Was Silicon Valley a more hospitable area for spinoffs than Dallas, possibly due to its prohibition on the enforcement of employee non-compete covenants (Gilson [1999])?

If agglomeration economies were not strongly at work in shaping the two clusters, a key question is how could spinoffs have fueled the growth of both clusters? Phrased differently, why wouldn't the spinoff process be a zero-sum game in which the gains of the spinoff came at the expense of its parent (or other firms in the region)? Fairchild demonstrates dramatically that this was not the case in semiconductors. In 1980, four of its spinoffs, Signetics, National, Intel, and AMD, accounted for 32% of the market along with Fairchild's 7% whereas on its own Fairchild's market share never exceeded 13%. Somehow spinoffs must have to some degree done things differently from their parents. Clearly, the theory sketched out in the paper, which features spinoffs inheriting traits from their parents, does not tell such a story. Any attempt to go from the theory to questions about policy regarding clusters, though, will require such a story.

The theory itself and some of the findings raise a number of additional questions about the spinoff process. First, do leading firms have more spinoffs because there is more to learn in such firms or merely because they are larger and have more candidates to form spinoffs? In both industries, the number of spinoffs per employee seems to have been lower in the larger firms (Klepper [2009]), which accords with the findings of general studies of entrepreneurship (Sorensen [2007], Elfenbein, Hamilton, and Zenger [2008]). But is the total number of employees the right denominator to compute the spinoff rate? The leading spinoffs in automobiles and semiconductors tended to be formed by very high level employees, some of whom were even founders of their firms

(Klepper [2009]), and the number of such candidates to form spinoffs may not vary greatly across firms of different size.

A related question about learning involves from whom do spinoff founders learn? In both industries, this was operationalized empirically by linking spinoffs to the prior employer of their main founder. But many spinoffs involve multiple founders and founders sometimes work for more than one firm in the same industry, which seems to have been particularly true for semiconductor firms as the industry evolved. In automobiles an attempt was made to take into account secondary founders and earlier auto employers of the main founder in the analysis of firm performance. In contrast, this was not done in semiconductors, in part because of the absence of the requisite data but also because it would have made it more difficult to sort out the distinctive heritage of spinoffs in Silicon Valley given the pervasive influence of Fairchild. Indeed, even defining spinoffs can run into some of the same issues. For example, National Semiconductor was defined as a spinoff of Fairchild, which is common, but National was a pre-existing Connecticut semiconductor company before it hired Charles Sporck, Fairchild's head of production, to reconstitute the firm in Silicon Valley. Should it be classified as a spinoff with Fairchild as its parent?[46] Addressing questions like these may require yet more discriminating data, which certainly will be a challenge.

It is not hard to come up with yet further questions about spinoffs and clusters, some quite fundamental. A key question is whether a similar process involving spinoffs operated to shape the geographic structure of other industries besides automobiles and semiconductors? Another key question that was alluded to earlier was why the firm spinoff rate was so much higher in Detroit and Silicon Valley? Did it have something to do with the law on employee non-competes (cf. Gilson [1999], Stuart and Sorenson [2003], Marx, Strumsky, and Fleming [2009]), might it have had something to do with peer effects, with (successful) spinoffs encouraging other employees to do the same (cf. Nanda and Sorensen [2009]), and/or might it have reflected a kind of localized external economy associated with the organizing and finance of startups (Kenney and Florida

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[46] Similar questions arise concerning firms with experience producing other products prior to entry. Should they be required to produce these products for some minimum amount of time to qualify as diversifiers? How should firms be treated that are started by individuals that previously headed another, related firm?

[2000])? Why did spinoffs generally locate close to home and why does this appear to be generally true of new firms (Figueiredo, Guimaraes, and Woodward [2002], Buenstorf and Klepper [2006], Dahl and Sorenson [2008])?

The analysis of both industries focused only on the emergence and growth of their clusters and the base location of entrants, but over time activity in both industries shifted away from their clusters via branching and related actions, as appears to be true generally (Dumais, Ellison, and Glaeser [2002]). What can be learned from these patterns about the forces governing the evolution of clusters? While attention focused on the early evolution of the Detroit and Silicon Valley clusters, it is hard to overlook the continued vibrancy of Silicon Valley (Zhang [2003]) compared to the decline of Detroit. Could this have something to do with agglomeration economies or in time will Silicon Valley inevitably decline like Detroit?

It is tempting to close by not trying to address the various questions raised, which clearly will require a lot more study. But theorizing and evidence related to a number of the questions offers some relevant insights. Regarding the geographic influence of spinoffs in other industries, Buenstorf and Klepper [2009] argue that spinoffs, and more broadly organizational reproduction and heredity, also played a key role in the historical agglomeration of the U.S. tire industry around Akron, Ohio. At the same time, Klepper [2008] implicates the lack of successful spinoffs as a key factor causing the U.S. television receiver to become less agglomerated over time. As to why spinoffs occur, Olds Motor Works and Fairchild seem instructive. Both were innovative firms that experienced considerable internal turmoil associated with financial control by outsiders with little knowledge of their industries. This led their founders and many others to leave both firms to exploit ideas that their parent firm shunned but turned out to be successful (Klepper [2009]). In the case of the semiconductor industry, this could help explain why it became concentrated in Silicon Valley rather than Dallas. Similar forces seem to have been at work in other automobile and semiconductor firms and in other industries as well, which forms the basis of a disagreement theory of spinoffs that Klepper and Thompson [2009] use to explain various statistical regularities that have been accumulating concerning spinoffs in a number of industries, including autos and semiconductors. If firms are limited in their ability to evaluate promising ideas that arise from within, as featured in Klepper and Thompson [2009], this might help to explain how spinoffs are not merely a zero-sum game but fuel the growth of regions.

While these observations suggest that organizational reproduction and heredity may be important forces operating in many settings, questions abound about how they operate and influence the formation and growth of clusters. Much remains to be learned about what it means for organizations to have competences, where they derive such competences, and the extent to which they can change their competences over time. The fact that two such celebrated clusters as the automobile industry in Detroit and the semiconductor industry in Silicon Valley experienced such striking parallels in the way they evolved suggests that digging into the origins and performance of entrants in other industries may yield new insights into the emergence and growth of industry clusters.

Table 1: Automobile Entry by State and Background for the Leading Eight States, Ordered by Population

State	Total Entry	Diversifiers	Startups	Spinoffs
NY	98	35	48	15
PA	52	13	28	11
IL	70	25	39	6
OH	89	35	38	16
MO	27	8	17	2
MA	55	15	36	4
IN	69	23	30	16
MI	135	30	46	59

Table 2: Market Shares of Leading U.S. Automobile Firms, 1900-1925

Early Entrants	Entry Yr.	Entry Location	1900	1905	1910	1915	1920	1925
Pope	1895	Hartford, CT	36					
Stanley	1896	Watertown, MA		2				
Locomobile	1899	Bridgeport, CT	18					
Knox	1900	Springfield, MA	0.3					
Packard	1900	Warren, OH/Detroit, MI		2	2			1
H.H. Franklin	1900	Syracuse, NY		4				
White Sewing M.	1901	Cleveland, OH	0.02	4				
Olds/GM	1901	Detroit/Lansing, MI		26		1	2	1
Cadillac/GM	1902	Detroit, MI		16	6	2	1	1
Jeffery/Nash	1902	Kenosha, WI		16			2	3
Later Entrants								
Studebaker	1902	South Bend, IN			8	5	3	4
Anderson/Union	1902	Anderson, IN			2			
Ford	1903	Detroit, MI		7	18	56	22	44
Maxwell Briscoe/ Maxwell/Chrysler	1903	Tarrytown, NY/Detroit, MI		3	6	5	2	4
Buick/GM	1903	Flint, MI		3	17	5	6	5
Willys	1903	Terre Haute, IN			9	10	6	6
Reo	1904	Lansing, MI		4	4	2		
Stoddard	1904	Dayton, OH		1				
E.R. Thomas-Det./Chrysler	1906	Detroit, MI			4	1		
Brush	1907	Detroit, MI			6			
Oakland/GM	1907	Pontiac, MI			2	1	2	1
Hupp	1909	Detroit, MI			3	1	1	3
Hudson	1909	Detroit, MI			3	1	2	7
Paige-Detroit	1909	Detroit, MI						1
Chevrolet/GM	1911	Flint, MI				1	6	12
Saxon	1913	Detroit, MI				2		
Chandler	1913	Cleveland, OH					2	
Dodge Brothers/Chrysler	1914	Detroit, MI				5	7	5
Dort	1915	Flint, MI					1	
Durant	1921	New York, NY					3	
Detroit-area Firms			0	58	65	83	52	85

Table 3: Market Shares of Leading U.S Semiconductor Producers, 1957-1990

Receiving Tube Firms	Entry Year[a]	Metropolitan Location	57	60	63	66	75	80	85	90
General Electric	1951	Syracuse, NY	9	8	8	8	C	C	C	C
RCA	1951	Camden, NJ	6	7	5	7	4	3	2	
Raytheon	1951	Boston, MA	5	4	--	--	1	1	1	0.5
Sylvania	1953	Boston, MA	4	3	--	--				
Westinghouse	1953	Pittsburgh, PA	2	6	4	5	C	C	C	C
Philco-Ford	1954	Philadelphia, PA	3	6	4	3				
Other Early Leaders										
Texas Instruments	1953	Dallas, TX	20	20	18	17	20	19	18	15
Transitron	1953	Boston, MA	12	9	3	3	0.5			
TRW	1954	Los Angeles, CA	--	--	4	--	C	C	C	C
Hughes	1955	Los Angeles, CA	11	5	--	--	C	C	C	C
General Instrument	1955	Long Island, NY	--	--	--	4	3	2	1	0.5
Delco Radio (GM)	1956	Kokomo, IN	--	--	--	4	C	C	C	C
Fairchild	1957	Mountain View, CA	--	5	9	13	9	7	5	A
Motorola	1958[b]	Phoenix, AZ	-	5	10	12	8	11	13	17
Later Leaders										
Signetics	1961	Sunnyvale, CA			--	--	5	6	5	
Analog Devices	1965	Boston, MA				--	1	1	2	2
AMI	1966	Santa Clara, CA				--	4	2	1	1
National	1967	Santa Clara, CA					10	11	10	9
Harris	1967	Melbourne, FL					2	3	3	4
Intel	1968	Santa Clara, CA					7	10	10	17
AMD	1969	Sunnyvale, CA					2	5	7	6
Mostek	1969	Dallas, TX					2	6	A	
Micron Technology	1978	Boise, ID						--	0.5	2
VLSI Technology	1979	San Jose, CA						--	1	2
LSI Logic	1980	Milpitas, CA						--	2	3
Silicon Valley Share										
Leading firms[c]			0	5	9	13	38	42	42	38
Leaders + other ICE firms[c]							43	48	49	47

-- Firm was producer, but no market share data reported
C—captive producer in the listing of Integrated Circuit Engineering (ICE)
A—acquired by a semiconductor producer

a Dates for receiving tube firms and early leaders based on Tilton [1971]
b According to Tilton [1971], Motorola used semiconductors only for its own purposes before 1958
c Includes Raytheon, which was based in Silicon Valley as of 1975.

Sources: See Tilton [1971] for sources for 1957, 1960, 1963, and 1966 market share data; the 1975, 1980, 1985, and 1990 market shares are based on annual compilations of ICE

Table 4: Backgrounds of IC Entrants by Region

	Transistors	Diodes	Active Modules	Electronics	Other Firms	Total
Boston	5	6	9	11	48	79
Los Angeles	7	1	8	24	62	102
New York	8	6	12	27	71	124
San Francisco	4	2	1	10	68	85
Other	16	8	21	58	130	233
Total	40	23	51	130	379	623

Table 5: Spinoffs of Automobile Producers

Detroit-area Producers*

Firm	Years (through 1924)	# Spinoffs	# Leading Spinoffs	Leading Firm
Olds	1901-1908	7	3	Yes
Buick/GM	1903-1924	7	2	Yes
Cadillac	1902-1908	4	3	Yes
Ford	1903-1924	4	2	Yes
Maxwell Briscoe/Maxwell	1904-1924	4		Yes
Northern	1902-1910	3	1	
Hupp Motor Car Co.	1909-1924	3		Yes
Packard	1900-1924	2		Yes
Jackson	1902-1918	2		
C.H. Blomstrom	1903-1909	2		
Imperial	1909-1917	2		
Chevrolet	1911-1916	2		Yes
Saxon	1913-1922	2		Yes
Hupp Corp.	1911-1916	2		

Non-Detroit Area Producers*

Firm	Years (through 1924)	# Spinoffs	# Leading Spinoffs	Leading Firm
Haynes Apperson	1895-1924	2		
Duryea	1896-1907	2		Yes
F.B. Stearns	1898-1924	2		Yes
Berg	1902-1906	2		
Jeffery	1902-1924	2		Yes
Metz/American Chocolate	1903-1923	2		Yes
Stoddard	1903-1910	2		Yes
Lozier	1904-1915	2	1	
York	1905-1917	2		
Palmer & Springer	1907-1914	2		
Single Center	1907-1909	2		
Ideal	1911-1924	2		
Biddle	1915-1922	2		
Barley	1916-1924	2		

* Classified in Detroit area if majority of years of production there

Table 6: Coefficient Estimates of the Automobile Spinoff Logit Model (Standard Errors in Parentheses)

Variable	Coefficient Estimate
Leading Make	1.03 (0.28)***
Top 1 or 2 Make	0.90 (0.37)**
Yrs of Production	0.17 (0.06)***
Yrs of Production Squared	-0.005 (0.003)
Acq. By Auto Firm	0.85 (0.36)**
Acq. By Non-Auto Firm	0.88 (0.26)***
Not Producing	-0.42 (0.24)*
Detroit	1.02 (0.22)***
# Firm-year Observations	7762
Log Likelihood	-551.18

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 7: Entry Size Distribution of Automobile Startups and Spinoffs in the Detroit Area and Elsewhere

Size Category	% of 311 Non-Detroit Startups	% of 37 Detroit Startups	% of 90 Non-Detroit Spinoffs	% of 52 Detroit[a] Spinoffs	% of 30 Detroit[a] Spinoffs with Leading Parents	% of 22 Detroit[a] Spinoffs without Leading Parents
$1,000+	1.3	0.0	1.1	7.7	10.0	4.5
$500-$1,000	1.0	0.0	0.0	1.9	3.3	0.0
$300-$500	1.3	5.4	3.3	7.7	13.3	0.0
$100-$300	5.1	13.5	25.6	13.5	20.0	4.5
$50-$100	10.6	18.9	8.9	23.1	20.0	27.3
$25-$50	6.1	5.4	11.1	7.7	10.0	4.5
$10-$25	10.6	2.7	5.6	3.8	3.3	4.5
$5-$10	1.6	0.0	0.0	1.9	0.0	4.5
$2.5-$5	2.6	2.7	1.1	0.0	0.0	0.0
$1-$2.5	0.0	0.0	0.0	0.0	0.0	0.0
Unknown	8.7	10.8	8.9	13.5	6.7	22.7
Not Observed	51.1	40.5	34.4	19.2	13.3	27.3

a. At the time of entry

Table 8: Coefficient Estimates of the Automobile Hazard of Exit Models
(Standard Errors in Parentheses)

Variable	# Firms	Model 1	Model 2	Model 3
Age	714	0.97 (0.01)***	1.06 (0.01)***	1.06 (.014)***
Detroit	112	0.68 (0.12)***	1.00 (0.15)	1.00 (0.15)
Diversifiers	224		0.63 (0.12)***	0.63 (0.12)
C&W, Bike, Engine Diversifiers	113		0.70 (0.14)**	0.68 (0.14)
Spinoffs	142		0.66 (0.13)***	0.71 (0.13)***
Entry 1895-1904	219		0.83 (0.14)	0.84 (0.14)
Entry 1905-1909	271		0.99 (0.13)	0.95 (0.13)
Entry 1895-1904*Age	219		0.92 (0.02)***	0.92 (0.02)***
Entry 1905-1909*Age	271		0.96 (0.02)**	0.97 (0.02)*
Detroit Spinoffs	54		0.45 (0.26)***	0.77 (0.27)
Largest Top Spinoffs	9			0.13 (0.54)***
Next Largest Top Spinoffs	24			0.57 (0.28)**
Number of Firms	714	714	714	714
Log Likelihood		-1908.38	-1845.20	-1835.83

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 9: Coefficient Estimates of the IC Hazard of Entry Models (Standard Errors in Parentheses)

Variable	# Firms	Model 1	Model 2	Model 3
Geography				
Boston	46	1.67 (0.53)	1.32 (0.42)	1.18 (0.38)
Los Angeles	60	1.01 (0.35)	1.05 (0.35)	1.14 (0.38)
New York	102	0.96 (0.27)	0.77 (0.22)	0.87 (0.25)
Silicon Valley	13	2.05 (0.99)	1.73 (0.85)	2.10 (1.03)
Technology				
Transistor	61		5.67 (1.44)***	8.01 (4.74)***
Diode	74		2.05 (0.59)**	3.70 (2.27)**
Experience				
Transistor Exp	61			1.11 (0.06)*
Diode Exp	74			1.15 (0.08)*
Active Module Exp	225			1.61 (0.26)***
Leading Transistor	11			7.66 (4.81)***
Number of Firms	360	360	360	360
Log Likelihood		-482.93	-461.58	-439.16

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 10: Spinoffs of Semiconductor Producers

Silicon Valley Producers

Firm	Years (through 1986)	# Spinoffs	# ICE Spinoffs	# Top 20 Spinoffs	Top 20 Firm
Fairchild	1957-1986	24	14	7	Yes
National	1967-1986	9	4	1	Yes
Intel	1968-1986	6	6	2	Yes
Signetics	1961-1975	5	2	1	Yes
Intersil	1967-1981	4	2	0	Yes
Synertek	1973-1985	4	3	1	Yes
Semi Processes	1975-1985	4	1	0	
AMI	1966-1986	3	2	0	Yes
AMCC	1979-1986	3	2	1	
Seeq	1981-1986	3	3	1	
Amelco	1961-1986	2	0	0	Yes
Micro Power	1971-1986	2	1	0	
Raytheon/Rheem	1961-1986	1	0	0	Yes
Siliconix	1963-1986	1	0	0	Yes
Avantek	1965-1986	1	0	0	
AMD	1969-1986	1	1	1	Yes
Exar	1971-1986	1	1	0	
Cal-tex	1971-1975	1	0	0	
Nitron	1972-1985	1	0	0	
Zilog	1974-1986	1	1	1	Yes
Supertex	1976-1986	1	0	0	
Exel	1983-1986	1	0	0	

Non-Silicon Valley Producers

Firm	Years (through 1986)	# Spinoffs	# ICE Spinoffs	# Top 20 Spinoffs	Top 20 Firm
General Instrument	1960-1986	4	2	0	Yes
Texas Instruments	1952-1986	3	3	2	Yes
Motorola	1958-1986	2	2	1	Yes
Mostek	1969-1985	2	2	2	Yes
RCA	1950-1986	1	1	0	Yes

Table 11: Coefficient Estimates of the Semiconductor Spinoff Logit Model (Standard Errors in Parentheses)

Variable	Coefficient Estimate
Market Share	0.24 (0.04)***
Years of Production	0.35 (0.10)***
Years of Production Squared	-0.012 (0.003)***
Acq. By Semiconductor Firm	0.88 (1.13)
Acq. By Non-Semic. Firm	0.78 (0.57)
Silicon Valley	1.64 (0.49)***
# Firm-year Observations	1194
Log Likelihood	-128.55

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 12: Coefficient Estimates of Logit Model of Producing a Monolithic IC at Entry (Standard Errors in Parentheses)

Variable	# Observations	Coefficient Estimates
Geography		
Boston	79	-0.21 (0.28)
Los Angeles	102	0.49 (0.25)*
New York	124	0.34 (0.23)
Silicon Valley	85	2.54 (0.42)***
Technology		
Transistor	40	1.28 (0.40)***
Diode	23	0.04 (0.46)
Active Module	51	-0.51 (0.32)
Electronics	130	-0.82 (0.23)***
Other		
Entry Year	623	0.06 (0.01)***
Number of Obs.	623	623
Log Likelihood		-369.40

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 13: Coefficient Estimates of IC Hazard of Exit Models (Standard Errors in Parentheses)

Variable	# Firms	Model 1	Model 2	Model 3	Model 4
Geography					
Boston	79	0.72 (0.12)**	0.76 (0.13)*	0.77 (0.13)	0.75 (0.13)*
Los Angeles	102	1.00 (0.14)	0.94 (0.13)	0.94 (0.13)	0.94 (0.13)
New York	124	1.10 (0.14)	1.10 (0.14)	1.10 (0.14)	1.10 (0.14)
Silicon Valley	85	0.72 (0.12)*	0.70 (0.12)**	0.69 (0.12)**	0.99 (0.18)
Technology					
Pre-Transistor	32		0.43 (0.11)***	0.54 (0.41)	0.51 (0.15)**
Pre-Diode	20		0.60 (0.18)*	0.47 (0.43)	0.55 (0.17)*
Pre-Active Module	35		0.99 (0.20)	1.08 (0.56)	0.95 (0.20)
Pre-Electronics	98		1.25 (0.17)*	1.53 (0.46)	1.17 (0.16)
Post-Transistor	8		1.90 (0.75)	3.63 (5.42)	1.58 (0.62)
Post-Diode	3		0.99 (1.00)	0.99 (1.00)	0.98 (0.98)
Post-Active Module	16		1.33 (0.40)	0.60 (0.45)	1.28 (0.39)
Post-Electronics	32		0.90 (0.26)	1.15 (0.84)	0.85 (0.25)
Pre-Transistor Exp	32			1.00 (0.06)	
Pre-Diode Exp	20			1.02 (0.08)	
Pre-Active Module Exp	35			0.99 (0.05)	
Pre-Electronics Exp	98			0.99 (0.02)	
Post-Transistor Exp	8			0.93 (0.15)	
Post-Diode Exp	3			-----[a]	
Post-Active Module Exp	16			1.09 (0.07)	
Post-Electronics Exp	32			0.97 (0.08)	
Leading Transistor	11			0.48 (0.26)	0.47 (0.25)
Entry Cohort					
Entry 65-69	195	0.39 (0.13)***	0.47 (0.16)**	0.44 (0.16)**	0.49 (0.17)**
Entry 70-74	184	0.67 (0.16)*	0.68 (0.17)	0.66 (0.16)*	0.70 (0.17)
Tech. Frontier					
Monolithic At Entry	329				0.96 (0.10)
Firm Heritage					
Parent Top Firm	29				0.16 (0.07)***
Year Dummies	623	Yes	Yes	Yes	Yes
Number of Firms	623	623	623	623	623
Log Likelihood		-2460.56	-2448.05	-2445.82	-2433.62

a. Not identified

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

Table 14: Coefficient Estimates of IC Logit of Attaining Top 20 in Sales

Variable	# Obs	Model 1	Model 2	Model 3	Model 4
Geography					
Boston	79	-0.07 (0.68)	-0.40 (0.74)	-0.36 (0.79)	-0.31 (0.82)
Los Angeles	102	-0.81 (0.79)	-0.69 (0.83)	-0.89 (0.84)	-0.75 (0.85)
New York	124	-1.62 (1.06)	-1.63 (1.09)	-1.83 (1.10)*	-1.94 (1.12)*
Silicon Valley	85	2.27 (0.44)***	2.33 (0.49)***	1.65 (0.50)***	0.86 (0.58)
Technology					
Pre-Transistor	32		0.33 (1.10)	0.05 (1.12)	0.34 (1.15)
Pre-Diode	20		-0.34 (1.15)	0.09 (1.22)	0.61 (1.19)
Pre-Active Module	35		-----[a]	-----[a]	-----[a]
Pre-Electronics	98		-----[a]	-----[a]	-----[a]
Post-Transistor	8		-----[a]	-----[a]	-----[a]
Post-Diode	3		-----[a]	-----[a]	-----[a]
Post-Active Module	16		0.96 (1.13)	1.45 (1.26)	2.28 (1.28)*
Post-Electronics	32		0.53 (0.85)	0.60 (0.87)	1.25 (0.96)
Leading Transistor	11		2.20 (1.23)*	1.50 (1.26)	1.42 (1.26)
Entry					
Entry Year	623	-0.08 (0.03)**	-0.08 (0.04)**	-0.10 (0.04)***	-0.13 (0.05)***
Tech. Frontier					
Monolithic At Entry	329			-----[a]	-----[a]
Firm Heritage					
Parent Top Firm	29				3.01 (0.61)***
# Observations	623	623	623	623	623
Log Likelihood		-109.48	-97.47	-84.35	-70.14

a. Not identified

*** Significant at the .01 level; ** Significant at the .05 level: * Significant at the .10 level

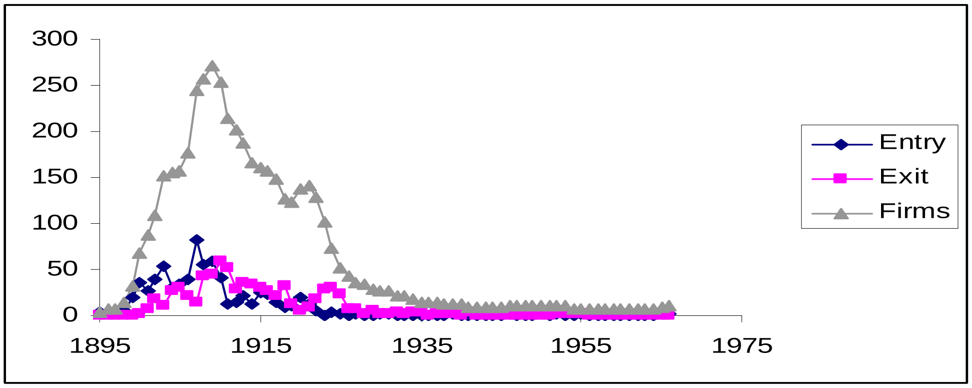

Figure 1: Entry, Exit, and Number of Automobile Firms, 1895-1966

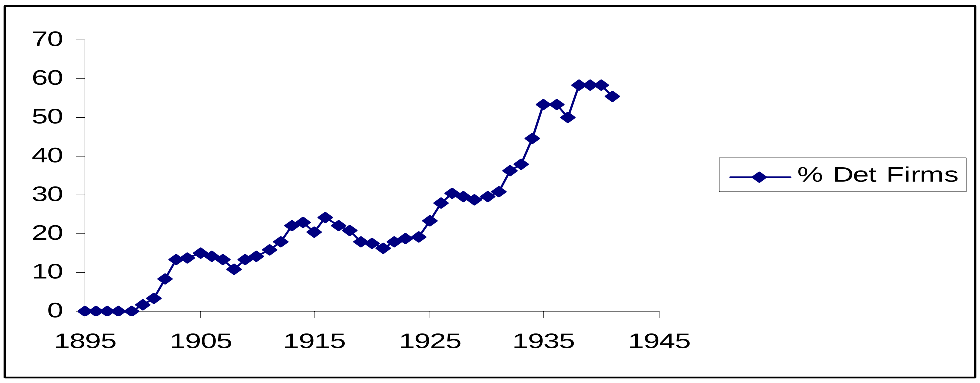

Figure 2: Percentage of Automobile Firms in the Detroit Area, 1895-1941

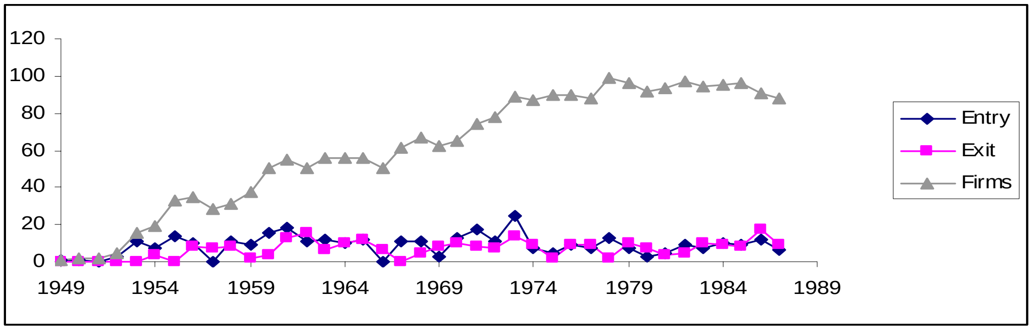

Figure 3: Entry, Exit, and Number of Transistor Firms, 1949-1987

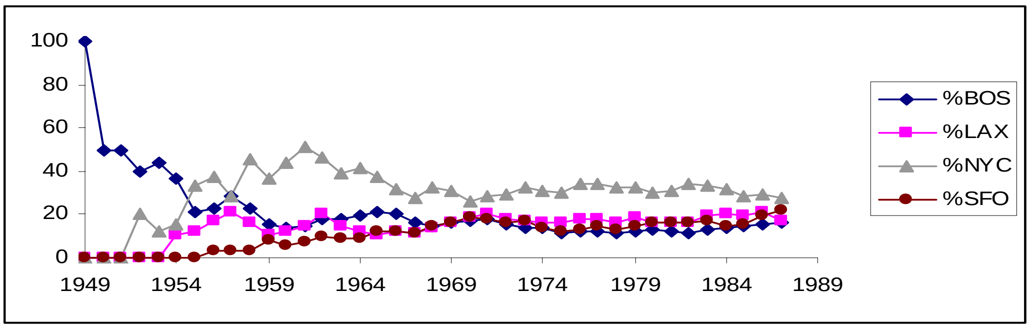

Figure 4: Percentage of Transistor Firms in Boston, Los Angeles, New York, San Francisco

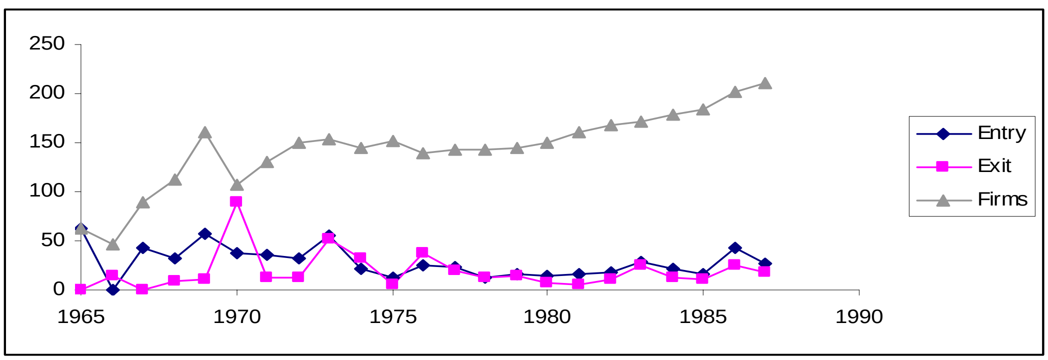

Figure 5: Entry, Exit, and Number of Integrated Circuit Firms, 1965-1987

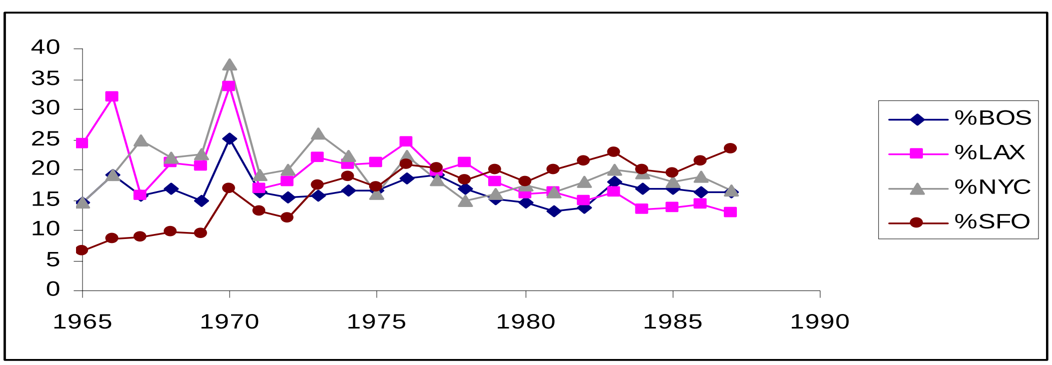

Figure 6: Percentage of IC Firms in Boston, Los Angeles, New York, San Francisco

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