FROM COMMUNITY OF INNOVATION TO COMMUNITY OF INERTIA: THE RISE AND FALL OF THE U.S. TIRE INDUSTRY

DONALD N. SULL
Harvard Business School
South Hall 211
Boston, MA 02163
telephone: 617 496-7179
fax: 617 495-3817
email: dsull@hbs.edu

ABSTRACT

Strategy scholars argue that industrial clusters foster innovation, citing examples such as Silicon Valley and Hollywood. Leading firms embedded in once-innovative clusters, such as Detroit's automobile manufacturers and Switzerland's watch makers, have failed to adapt to competitive changes and been accused of organizational inertia. This paradox raises two related questions: how do industrial clusters contribute to inertia as well as innovation and how might industrial clusters evolve to promote inertia rather than innovation. This paper presents findings from a historical analysis of the American tire industry concentrated in Akron, Ohio from its inception in 1900 to its demise in the late 1980s. The tire industry was among the most innovative sectors in the U.S. economy between 1900 and 1935, providing dramatic improvements in both product performance and manufacturing process efficiency, and Akron-based firms accounted for most of this innovation. Faced with the introduction of radial tire technology pioneered by French tire maker Michelin, however, the Akron tire companies faltered in the 1970s and 1980s, and in the span of eighteen months, three of the four Akron tire manufacturers ceased to exist as independent corporations. This paper presents a framework grounded in the historical data, that suggests that geographic co-location facilitates knowledge spillovers, but the value of these spillovers decrease as the technology matures. The cost of geographic co-location increases, however, as the cluster's shared cognitive models and organizational routines assume a taken-for-granted quality. The institutionalization of cognitive models and organizational routines leaves the cluster vulnerable to environmental jolts.

I gratefully acknowledge the cooperation of the Akron Beacon Journal, the Firestone Tire & Rubber Company, the United Rubber Workers, the Akron Public Library, B. F. Goodrich, and the University of Akron Historical Documents Department for full and open access to their internal files. Research support from the Division of Research at the Harvard Business School is gratefully acknowledged. I also thank Mike Tushman for his helpful comments.

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Strategy scholars argue that industrial clusters foster innovation, citing examples such as Silicon Valley and Hollywood. Leading firms embedded in once-innovative clusters, such as Detroit's automobile manufacturers and Switzerland's watch makers, have failed to adapt to competitive changes and been accused of organizational inertia. This paradox raises two related questions: how do industrial clusters contribute to inertia as well as innovation and how might industrial clusters evolve to promote inertia rather than innovation. This paper presents findings from a historical analysis of the American tire industry concentrated in Akron, Ohio from its inception in 1900 to its demise in the late 1980s. The tire industry was among the most innovative sectors in the U.S. economy between 1900 and 1935, providing dramatic improvements in both product performance and manufacturing process efficiency, and Akron-based firms accounted for most of this innovation. Faced with the introduction of radial tire technology pioneered by French tire maker Michelin, however, the Akron tire companies faltered in the 1970s and 1980s, and in the span of eighteen months, three of the four Akron tire manufacturers ceased to exist as independent corporations. This paper presents a framework grounded in the historical data, that suggests that geographic co-location facilitates knowledge spillovers, but the value of these spillovers decrease as the technology matures. The cost of geographic co-location increases, however, as the cluster's shared cognitive models and organizational routines assume a taken-for-granted quality. The institutionalization of cognitive models and organizational routines leaves the cluster vulnerable to environmental jolts.

Keywords: Cluster, knowledge, inertia

Industrial clusters have recently emerged as an important topic for both scholars and policy makers (Porter, 1990). Porter (1998:199) defines an industrial cluster as "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalties and complementarities." Prominent examples of clusters include financial services in New York and London, electronics in Silicon Valley (Saxenian, 1996), film production in Hollywood (Faulkner & Anderson, 1987), machine tools in Sakaki Township in Japan (Friedman, 1988), the aerospace electronics complex in Southern California (Scott, 1991) and a variety of industries in northern Italy (Brusco, 1982; Triglia, 1986; Lazerson, 1995). Economists have offered theoretical models and empirical evidence that clusters' concentration of specialized inputs and supporting institutions provide economies of agglomeration (Krugman, 1991) and knowledge spillovers (Aufdretsch & Feldman, 1996) which increase productivity, spur innovation and encourage new business formation (Baptista & Swann, 1998; Ciccone & Hall, 1996).

Despite the advantages they derive from geographic proximity, cluster members may also be more prone to inertia than organizations outside a cluster (Porter, 1998:243; Pouder & St. John, 1996), as evidence from several geographically concentrated industries suggests. The U.S. steel industry was historically concentrated in Pittsburgh, PA and the major firms in the cluster--U.S. Steel, Jones & Laughlin, National Steel and Wheeling-Pittsburgh each experienced great difficulties in responding to low-cost imports and mini-mill production technology (Hall, 1997). Detroit's failure to respond effectively to Japanese competitors is well documented (Abernathy, 1978; Helper, 1990). At their height, minicomputer firms located in the Route 128 area, including Digital Equipment, Wang, Data General and Prime, accounted for more than two-thirds of the industry's value-added (Saxenian, 1996:18), but failed to respond effectively to the rise of personal computers. Business historians have documented the decline of once-dominant industrial clusters including cotton textiles in Lancashire (Lazonick, 1981), specialty steel in Sheffield (Lloyd-Jones & Lewis, 1994), copper smelting in Swansea, Wales (Newell, 1990), and watch making in Jura, Switzerland (Glasmeier, 1991).

While scholars have analyzed how clusters contribute to innovation, with a few exceptions (Porter, 1998; Pouder & St. John, 1996), they have largely ignored the question of how clusters can contribute to organizational inertia and how an innovative cluster can evolve over time from a community of innovation to a community of inertia. This paper presents findings from a historical analysis of a single industrial cluster--the American tire industry concentrated in Akron, Ohio--from its inception in about 1900 to its demise in the late 1980s. The tire industry was among the most innovative sectors in the U.S. economy between 1900 and 1935, providing dramatic improvements in both product performance and manufacturing process efficiency, and Akron-based firms accounted for most of this innovation and came to dominate the industry. Faced with the introduction of radial tire technology pioneered by French tire maker Michelin, however, the Akron tire companies faltered in the 1970s and 1980s, and in the span of eighteen months, three of the four Akron tire manufacturers ceased to exist as independent corporations. This paper also presents a framework grounded in the historical data to illuminate how clusters can contribute to inertia and the processes by which a cluster can evolve from fostering innovation to inertia.

INDUSTRIAL CLUSTERS, INNOVATION, AND INERTIA

Marshall (1890:222-231) wrote the seminal theory on geographic concentration of industries, and recent work in trade theory (Krugman, 1991) and strategy (Porter, 1998) has built on Marshall's foundation. These scholars characterize industrial clusters as geographically concentrated groups of related organizations, including competitors, suppliers, customers, universities, and trade organizations (Porter, 1998:197). Clusters can improve member firms' productivity thorough proximity to critical raw materials or transportation routes (Marshall, 1890:223-224). The geographic concentration of an industry can also attract employees with specialized skills and a broad base of suppliers which specialize in serving the industry (Marshall, 1890:226). The co-location of providers of critical, specialized resources results in "economies of agglomeration," by which the benefits of locating within a cluster increase with the number of other firms in the cluster (Krugman, 1991). In each of these cases, clusters increase productivity by bringing together necessary resources.

Marshall suggests another benefit of clusters that hinges on the transfer of knowledge rather than the co-location of resources. Marshall (1890:226) writes:

> The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes, and the general organization of business have their merits promptly discussed; if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas.

Marshall's quote evokes an image of the industrial cluster as a geographically co-located community of experts whose shared understanding of an industry allows them to rapidly evaluate and extend innovations arising within the cluster, which contributes to an ongoing cycle of cumulative innovation. Marshall's description of clusters that facilitate knowledge transfer is consistent with recent empirical research. Saxenian (1996:29-57) describes how the tightly knit community of semiconductor engineers and executives in Silicon Valley cumulatively built on one another's process and product innovations through close monitoring and frequent collaboration across firm boundaries. Brown & Duguid (2000:141-143) use the term "community of practice" to describe face-to-face communities which "form the social networks along which knowledge about that practice can both travel rapidly and be assimilated readily," and use this construct to help explain how other Silicon Valley-based firms were able to understand and build upon innovations originating in Xerox PARC, while managers in Xerox's Connecticut headquarters and development engineers in Dallas research labs were unable to leverage these innovations (Brown & Duguid, 2000:150-151). Analyzing a large sample of patent citations, Jaffe et al. (1993) established that knowledge spillovers are geographically localized. Consistent with Marshall's theory, these studies suggest that geographic concentration can result in a community that facilitates the transfer of knowledge and thereby promotes cumulative innovation.

The high level of mutual interaction, awareness of a common enterprise, and patterns of competition and coalition qualify the industrial cluster as an organizational field (DiMaggio & Powell, 1983; Pouder & St. John, 1996), and therefore susceptible to analysis through the lens of institutional theory. Early institutional theorists (Selznick, 1949) viewed organizations as embedded in local communities, but recent institutional theorists have shifted focus to non-local environments including industries and professional fields (DiMaggio & Powell, 1991:13). Industrial clusters, however, represent an interesting unit of analysis for institutional theory because they lie at the intersection of a local community and an industry, and this overlapping of local communities and industry might be expected to intensify institutional forces.

According to institutional theory, entrepreneurs in an emerging field must struggle to overcome the liability of newness (Stinchecombe, 1965) which results in part from ambiguity about the causal links between organizational means and ends (DiMaggio & Powell, 1983). Entrepreneurs face high levels of uncertainty about which organizational routines are most appropriate (Nelson & Winter, 1982) and which product design to adopt (Abernathy, 1978; Anderson & Tushman, 1990). Organizations that monitor alternative routines and product designs and modify and improve upon these innovations increase their chances of surviving industry shake-outs (Klepper & Graddy, 1990; Klepper, 1996). Monitoring, adapting and adopting organizational routines, however, entails the transfer of tacit knowledge that is difficult to codify and transfer across organizational boundaries (Liebeskind et al., 1996). Geographic co-location can reduce the costs of monitoring and adapting routines and innovations in product design by increasing the density of social networks that facilitate the flow of tacit knowledge (Powell, 1990). Entry into the social network through which tacit knowledge flows requires entrepreneurs to establish their legitimacy, which they may do by mimicking prevailing organizational routines and conforming to the "dominant normative structure" within the community (Scott, 1992:16). The legitimacy resulting from conformance to dominant norms allows entrepreneurs to secure not only access to tacit knowledge, but also to necessary resources including funds and employee commitment (Aldrich & Fiol, 1994; Lomi, 1995).

Over time, the routines and norms which prevail within the industrial cluster at its inception may assume a taken-for-granted quality (Berger & Luckman, 1967; Zucker, 1977). Although the level of technical uncertainty may decrease as the industry matures, organizations within the cluster will continue to imitate the actions of peers within the cluster (DiMaggio & Powell, 1983), and the cluster members' geographic proximity may facilitate mimetic isomorphism. Common sources of information and frequent interaction with like-minded managers may reinforce the cognitive models of competition shared by managers within the industrial cluster (Pouder & St. John, 1996). The deep embedding of economic transactions in the cluster's social networks (Granovetter, 1986) might be expected to increase the social sanctions associated with deviations from established practices (Biggart, 1989) and increase both the ease of and pressure for normative isomorphism (DiMaggio & Powell, 1983) among organizations within the cluster. Thus, institutional theory suggests that the overlapping of industry and local community in an industrial cluster could impart on the cluster some of the characteristics of a total institution (Goffman, 1961). These institutional pressures, in turn, might contribute to organizational inertia, which would prevent firms within the cluster from changing rapidly enough to effectively adapt to changes in their competitive environment (Hannan & Freeman, 1984).

METHODS

This study adopts an embedded case study design (Yin, 1984) that explores the evolution of the U.S. automotive tire industry at the level of the industry as a whole, the cluster centered in Akron, Ohio and constituent firms. This study takes a historical perspective, covering the period between the emergence of the automotive tire industry in the early 1900s through to 1988, by which time only a single major U.S. tire manufacturer remained after all others had been acquired by European or Japanese competitors. The long time horizon provided by historical analysis offers a powerful lens for studying the evolution of institutional processes over time (Aldrich & Fiol, 1994; Barley & Tolbert, 1997).

Historical archives were the primary source of data for the period between the industry's founding and initial concentration in Akron and the introduction of radial tire technology to the U.S. market approximately 65 years later. I secured full or limited access to the corporate archives of the four major U.S. tire producers located in Akron. I also examined archival data from several organizations located in Akron which served the tire industry, including the city's newspaper, the tire industry labor union, the leading independent tire testing laboratory and the local university (see Table 1 for an overview of archival data sources). These archival data were supplemented with secondary sources including government documents, previous histories of the tire industry, doctoral dissertations and scholarly articles. Approximately 40 taped interviews were conducted with former tire industry executives, union officials and industry experts covering the period between the late 1960s and the 1990s. The interviews were open-ended ethnographic in format (Spradley, 1979), but informants were encouraged to choose episodes which they considered important in understanding how the tire producers responded to radial technology. All interviews were tape recorded and fully or partially transcribed.

INSERT TABLE 1 ABOUT HERE

To analyze the data, I created a database of key events indexed by level of analysis--i.e., tire industry, Akron cluster as individual organization, date and data source. I then generated a set of conceptual labels to code the events. These categories were not derived from existing theories, but emerged inductively from the data (Strauss & Corbin, 1990:61-74). In some cases, such as product design innovation, the categories emerged naturally from my framing of the phenomenon. Other categories were unexpected, however, including the importance of process (rather than product) innovation, the difficulty of exiting from old technology when adopting new technology and the central role played by social institutions like the Akron residential neighborhoods and country club.

After the preliminary coding, I created a time-ordered matrix (Miles & Huberman, 1994:119-122) for the tire industry as a whole, each of the Akron clusters, the four large Akron-based tire firms and two tire firms outside of Akron--i.e., U.S. Rubber and Michelin. For each matrix I labeled the rows by categories. To test the validity of my emerging eras and categories, I gathered quantitative data at this point. The eras for the industry time-ordered matrix, for example, consisted of four eras--entry, shakeout, stability and jolt--and I gathered data on firm entry and exit by year to test and refine my emerging eras and categories. I then used these matrices to structure and write individual case studies and then compared across these case studies (Eisenhardt, 1989), and used these comparisons as a basis for a matrix for the cluster as a whole. At this point, I began to explore theoretical perspectives that might help sharpen my emerging framing, and found institutional theory (Meyer & Rowan, 1977; Zucker, 1977; DiMaggio & Powell, 1983) and recent writing on communities of practice (Saxenian, 1996; Brown & Duguid, 2000) to be particularly useful. After several iterations between theory and the data, I generated the time-ordered matrix for the Akron tire cluster between 1900 and 1988 found in Figure 1.

INSERT FIGURE 1 ABOUT HERE

Innovation in the tire industry: 1900-1935

Although currently mature, the tire industry was among the most dynamic industries in the United States between 1900 and 1935 and held a position analogous to Silicon Valley's semiconductor industry in the 1960s and 1970s. Like semiconductor companies, tire manufacturers produced a critical component to one of the fastest growing products in the world. Unit production of automobiles increased one thousand fold from approximately 4,000 automobiles in 1900 to over four million by 1923 (A.A.M.A., 1994:3). Like semiconductors, both the design and production of tires were technically sophisticated, and the rubber industry ranked fourth among all U.S. industries in the total number of scientific personnel employed (after chemicals, electrical machinery and metals) and second in research intensity measured by research personnel as a percentage of total employees (Chandler, 1990:108). The leading firms in the tire industry were concentrated in a single city, Akron, which was known as America's "Rubber Capital," and grew faster than any other U.S. city between 1910 and 1920 (Gaffey, 1940:161).

The tire industry attracted hundreds of entrepreneurs between 1900 and 1927, with the total number of firms peaking in 1919 through 1922 at 190 to 274 firms (Table 2).[1] New entrants were attracted by the possibility of entrepreneurial profits. In 1920, two Akron-based journalists estimated that 122 tire industry entrepreneurs and investors had achieved millionaire status in that city alone (Allen, 1949:175-176), and the most successful entrepreneurs, including Harvey Firestone and B.F. Goodrich, became household names.

INSERT TABLE 2 ABOUT HERE

The period of entry was followed by a "shakeout" marked by a sharp decline in the number of producers (Klepper & Graddy, 1990). By the mid-1930s, the total number of tire manufacturers declined to between 35 and 53 (see Table 2), with 81% of the exits resulting from failed firms and 19% from mergers and acquisitions (French, 1986:33). These exits were concentrated in the period between 1921 and 1931, and most occurred prior to the onset of the Great Depression in 1929, although the number of firms continued to decline throughout the 1930s. As the industry as a whole experienced a shakeout, the four largest competitors gained market share. In 1919, the four largest tire manufacturers were among the largest 100 U.S. industrial corporations measured by assets and accounted for 55% of tire unit shipments (Table 3). By 1935, the four largest firms accounted for 80% of shipments.

INSERT TABLE 3 ABOUT HERE

Not only was the tire industry concentrated among a few firms, it was also concentrated geographically. Although Akron-based firms represented only 8-13% of total tire producers throughout the 1920s, three of the four largest tire producers (i.e., Goodyear, Firestone, and B.F. Goodrich) had their headquarters in Akron. By the mid-1930s, Akron-based General Tire had grown to the fifth largest tire manufacturer in the United States, which meant that four of the so-called "Big Five" tire companies had their headquarters in Akron. By 1930, Akron factories produced approximately 65% of all tires manufactured in the United States (Sobel, 1951:12).

Scholars have offered alternative hypotheses to explain the emergence of the leaders in the tire industry. Chandler (1990:105-106) argues that the leading tire manufacturers succeeded in part through their early investment in large factories, which conferred manufacturing economies of

[1] Table 2 reports estimates of total firm and plant numbers, entries, exits and firm locations from two different sources. Columns one through four report estimates based on estimates found in French (1986:33) based on corporate archival data, U.S. Government hearings and trade publications. Columns five through eight report data gathered from *Thomas' Register of Manufacturers*, which have been reported elsewhere (Klepper & Simons, 1997:2000). The counts of companies derived from *Thomas' Register* consistently exceed French's estimates, and may include some firms which distributed tires without manufacturing them. French's sources may possibly exclude less established firms. The two data series provide lower and upper ranges of tire companies, and reveal consistent patterns of entry and exit timing.

scale. Careful estimates of the economies of tire manufacturing, however, suggest that tire factories achieve minimum efficient scale at 4,000 to 10,000 tires per day, which translated into approximately 2-3% of total domestic production (Bain, 1956:72, 238; F.T.C., 1966:20). Akron's large factories may have resulted in diseconomies of scale (Reynolds, 1938:466). Chandler and others (Chandler, 1990:107; Knox, 1963:157-158) argue that Firestone, Goodyear, and B.F. Goodrich succeeded in part by investing heavily in distribution, but French (1986:40-41) demonstrates that the tire company-owned retail stores accounted for less than 1% of industry sales as late as 1928, and that the tire firms' investments in building a controlled retail distribution network began in earnest in 1929 and 1930, after the Akron firms had already established their preeminence.

The ability of Akron-based firms to consistently innovate in product and manufacturing process technology provides a more promising lens for understanding why Akron firms came to lead the tire industry (Stern, 1933; Carlsmith, 1934:124-127; Fraser & Doriot, 1932:100-103; Warner, 1966; Klepper & Simons, 1997:2000). A series of innovations in raw materials, tire construction and rim design yielded dramatic improvements in product performance between 1900 and 1937. The average tire manufactured in 1900 lasted an approximately 500 miles, while the typical tire produced in the mid-1930s lasted more than 20,000 miles (Jeszeck, 1982:396). Tire performance also improved in terms of smoothness of ride, ease of changing, fuel efficiency and safety over this period (Warner, 1966). Increased product performance was accompanied by lower prices, and the U.S. Bureau of Labor Statistics calculated that the price of the average tire declined by 80% between 1913 and 1933 (U.S. Bureau of Labor Statistics, 1934).

The dramatic improvements in tire performance did not result from a single innovation, but rather from a steady stream of incremental improvements in design that cumulatively increased tire performance (Reynolds, 1938:463; Gaffey, 1940:90). Automotive tires were initially constructed with thin strips (or plies) of cotton fabric, which was impregnated with rubber then coated with a thicker layer of rubber to form the tread surface that meets the road. The cross threads of the woven fabric, however, rubbed against one another when the tire moved, and the heat from the resulting friction capped the tire's maximum useful life at 2,000 to 4,000 miles. The cord tire, which was introduced in the United States in 1920 by Diamond, removed the cross threads from the woven fabric, thereby reducing friction and increasing the potential maximum life of a tire to 10,000 miles. In 1922, Firestone introduced the balloon tire, which used fabric dipped in rubber (known as "gum-dipped") to allow a wider tire with lower air pressure that increased the maximum potential life to 15,000 to 20,000 miles. Three years later, Goodyear introduced a modification of the balloon tire with 6 to 8 plies (instead of the customary 4 plies), which offered the possibility of longer useful life. Figure 2 graphs the percentage of domestic tire shipments by construction from 1910 to 1933 and demonstrates that the tire industry moved through several designs in that period before settling on the 6- to 8-ply balloon tires as the dominant design by the mid 1930s.

INSERT FIGURE 2 ABOUT HERE

Changes in tire construction offered the potential for improved performance, but realizing this potential required a host of innovations in complementary technologies (Rosenberg, 1979), especially the raw materials needed to construct a tire, i.e., chemical additives, steel wire, and textiles (Warner, 1966). Cord tires, for example, reduced tire failure resulting from fabric friction, but not from rubber degradation. The gas and carbon blacks developed by Diamond between 1910 and 1912, however, significantly increased the durability of tread rubber (Warner, 1966:82).

Advances in steel wire were necessary to allow the balloon tire to attach to a rim (Dick, 1980). Tire manufacturers also innovated in the design of the rim, which connects the tire to the wheel of the automobile. Goodyear, for example, developed the Universal Rim, to stimulate demand for its straight-side tire, which could not attach to the clincher-style rim that represented the industry standard interface until the mid-1920s (O'Reilly, 1983:18-23). Table 4 summarizes the major innovations between 1899 and 1939, and demonstrates that Akron-based tire firms accounted for the majority of innovations in tire construction, rim design and raw materials.

INSERT TABLE 4 ABOUT HERE

In addition to product innovations, the tire industry also experienced improvements in manufacturing process technology that dramatically increased labor productivity between 1914 and 1937. Industry-wide labor productivity increased between five-fold (when measured by tires produced per man-hour) and six-fold (when measured by pounds of rubber processed per man-hour) between 1914 and 1937 (Gaffey, 1940:69). Between 1914 and 1927, the tire industry experienced the largest percentage increase in labor productivity in a sample of eleven manufacturing industries selected for their rapid growth in productivity (U.S. Bureau of Labor Statistics, 1930:501-517), and experienced the second highest rate of labor productivity growth between 1914 and 1931 (U.S. Bureau of Labor Statistics, 1936:707-736).

The Bureau of Labor Statistics analyzed the manufacturing process innovations that drove these improvements in labor productivity and concluded that: "The tire industry offers an instance in which the increased productivity of labor was due more to the so-called evolutionary small changes in production rather than to any revolutionary change in the process of tire manufacturing." (Stern, 1933:24). The Bureau of Labor Statistics' analysts identified 135 manufacturing process innovations in six large tire plants between 1928 and 1931 and quantified their impact on labor productivity by measuring the reduction in worker-hours per day that stemmed from the innovation. An analysis of these 135 manufacturing process innovations supports the Bureau's conclusion that improvements in labor productivity resulted from a series of small process innovations rather than a single radical change in the production process. The largest single process innovation accounted for only 8.5% of the total increase in labor productivity, and the remainder of the productivity gains resulted from a large number of small innovations (Figure 3).

INSERT FIGURE 3 ABOUT HERE

Like the innovations in tire design and raw materials, the manufacturing process improvements appear to have been concentrated among Akron's tire firms. The one non-incremental process innovation identified in the Bureau's report--the tire building machine--was developed by B.F. Goodrich and Goodyear between 1904 and 1909 (O'Reilly, 1983:38; Blackford & Kerr, 1996:54). The Bureau's report also provides evidence that Akron's five largest factories achieved higher levels of productivity and achieved these improvements more quickly than the industry as a whole. The continuous stream of product and manufacturing process improvements which emerged from the Akron-based firms allowed them to gain market share among the demanding OEM customers, particularly General Motors, Ford and Chrysler, which together accounted for 72% of all new cars sold by 1929 (French, 1991:53). The higher levels of labor productivity enjoyed by the Akron firms also allowed them to earn a profit despite steady declines in tire prices. In a statistical analysis of all U.S. tire firms, Klepper & Simons (2000) find that firms located within 50 miles of Akron were more likely to be at the leading edge of technology and that their technical leadership materially increased their probability of survival.

Local institutions facilitated the transfer of knowledge among Akron's tire firms. In 1909, a consortium of executives from Akron's tire companies funded the construction of America's first laboratory devoted to rubber chemistry at Buchtel college (the precursor of the University of Akron), and this laboratory served as a focal point for collaboration among the local tire companies on basic and applied research (Love & Giffels, 1999:303). The *Akron Beacon Journal*, the flagship paper of the Knight family newspaper chain, provided in-depth coverage of Akron's tire industry beginning in 1903 and quickly emerged as the industry's journal of record. In the early 1920s, Akron-based Smithers Scientific began providing independent technical analysis of tire design and performance by reverse engineering tires, a service which helped competitors track and understand one another's product innovations.

The Akron-based tire firms also appeared to follow an "open-door" policy in which executives "did not worry too much about patents and trade secrets. One company got an idea, another improved on it, and a third brought in a new variation, with the result that the whole industry went ahead, virtually pooling ideas which would expand the business." (Allen, 1949:167). When companies did attempt to patent their innovations, their applications were either denied as a logical extension of the current state of the art or granted for very narrow protection which other firms easily circumvented (Warner, 1966:298). The Akron tire firms often collaborated on technical projects. B.F. Goodrich and Diamond jointly formed a company to reclaim used rubber in 1904 (Blackford & Kerr, 1996:50), and Goodyear and Firestone collaborated closely to create a common standard for rims that would allow them to mount their straight-side tires (O'Reilly, 1983:41). Goodyear's P.W. Litchfield, who initiated Goodyear's research department in 1900 and later rose to the presidency, believed that "a company which closed its doors was apt to lock out more information than it locked in." (Allen, 1949:167).

Local social networks also created personal relationships among tire industry executives that cut across firm boundaries. Tire industry junior and senior executives congregated in the same residential neighborhood in West Akron, which had emerged as the primary residential section for Akron's tire industry (Allen, 1949:175). The Portage Country Club, which was founded by two B.F. Goodrich executives in 1894, provided a setting where tire industry entrepreneurs, executives, and financiers regularly socialized (Zonsius, 1994:vii-viii). A cross check of the Portage Country Club 1906 membership roster against company histories reveals that the four major Akron tire companies were well represented among club members (Table 5). All of the living founders of the large Akron tire companies were members, as was M. O'Neil, who would go on to found General Tire in 1915, and technical and other executives were well represented. This analysis has not captured executives from non-surviving companies without corporate histories, and may exclude lower-level executives from the surviving companies, and it is likely that the actual number of club members involved in the tire industry in 1906 was higher than the numbers reported in Table 5.

INSERT TABLE 5 ABOUT HERE

Institutionalization in Akron: 1935-1965

If a group of Akron tire industry executives were transported from the 1930s to the 1960s, they would have found that remarkably little had changed in the intervening decades. The same five tire companies still accounted for more than three-quarters of U.S. sales, and no new domestic tire producer had entered the market since the 1920s. (Federal Trade Commission, 1966). Goodyear, Firestone, B.F. Goodrich and General Tire retained their headquarters in Akron, which remained America's undisputed "Rubber Capital." The product and process technology were also stable, and the typical tire manufactured in the United States in the 1960s had the same basic construction, lasted as long and was produced using essentially the same manufacturing process as a tire produced three decades earlier (Jeszeck, 1982:396).

The executives who rose to the top of Akron's tire companies were deeply steeped in the local community. Executive filtering can serve as a powerful mechanism to perpetuate institutions (DiMaggio & Powell, 1983), and the executive promotion processes within Akron's tire companies elevated managers from the Akron community. An Akron native led Goodyear as either president or chairman of the board continuously between 1940 and 1983 (Love & Giffels, 1999:80). In 1972, between one-third and two-thirds of the executives at Goodyear, Firestone and General Tire were Akron natives; between one-third and one-half had risen through the ranks of the domestic tire industry; and a significant percentage had followed in their fathers' footsteps as executives in the same company (Table 6). Industry insiders referred to these homegrown executives as "gum-dipped," in reference to the production process developed by Firestone in the 1920s in which fabric strips were dipped in rubber and thereafter took on a uniform shape (Millis, 1994).

INSERT TABLE 6 ABOUT HERE

These executives remained deeply engaged in the local community, and most of them lived within a five block radius of one another (Nevin, 1994). Tire industry executives vied for membership in the Portage Country Club and aspired to rise through the ranks of the club as a Junior, Associate, Resident and Honorary member (Zonsius, 1994:36-37). "On Friday and Saturday nights," one industry insider recalled, "everybody who was anybody in the tire industry drank at the Portage Country Club." (Stoyer, 1995). Akron tire executives also vied for positions on the boards of local charities (Love & Giffels, 1999:211-225) and monitored other companies' contributions to the United Way to ensure that their contributions matched or exceeded their local rivals' donations (Firestone Minutes of the Board, 25 June, 1974). Tire executives relied on the local newspaper for information on the local community, and one industry observer recalled that: "More tire executives in Akron only read the *Akron Beacon Journal* and believed that anything worth knowing would be printed there." (Millis, 1994).

The tire industry enjoyed brisk growth in demand after the Second World War, with total industry shipments increasing from 43 million units in 1935 to 146 million units in 1965. The Akron tire companies responded to this growth in demand by constructing new tire factories. Table 6 lists each U.S. passenger tire plant built by year, location, and competitor for the four Akron-based tire companies as well as two non-Akron competitors--i.e., U.S. Rubber and Michelin. Table 6 shows that the four Akron firm constructed 15 factories between 1935 and 1965, while U.S. Rubber built only one new plant over that period. Table 6 also reveals that the Akron-based competitors clustered their new plant construction both temporally and geographically. Three of the Akron companies built factories in Los Angeles in the early 1920s, and in the Midwest in 1937; then again the Midwest in the mid-1940s. U.S. Rubber did not build a single new plant during this period. By the mid-1960s, Akron tire makers officially collaborated through the Rubber Manufacturers' Association to develop consensus projections of industry growth that consistently forecast steadily rising demand (Shleifer, 1981), and based on their consensus forecasts, the Akron firms accelerated their rate of new plant construction. A former president of Firestone characterized the industry in this period as “a no-brainer industry … planning consisted of deciding where to put up the next factory.” (Brodeur, 1994:3).

INSERT TABLE 7 ABOUT HERE

The Akron-based tire companies also shared the belief that serving Detroit’s automobile OEMs was still critical to their success in the tire industry and competed fiercely with among one another to win OEM business. In the late 1960s, Firestone remained the leading supplier to Ford sixty years after Firestone began as the leading supplier of tires for the Model T, and Goodyear remained the lead supplier to Chrysler and American Motors, a position it had held since 1907 (Federal Trade Commission, 1966:26), and in the late 1960s, sales to Detroit’s OEMs accounted for at least 25% of unit shipments for the leading firms. While close ties to OEMs undoubtedly contributed to the emergence of Firestone, Goodrich and Goodyear as industry leaders, it was less clear that their continued focus in serving the OEM market was still justified in the 1960s. OEMs exercised their considerable buying power to demand large capital investments from their tire suppliers and negotiate prices as much as 50% below replacement industry levels (Federal Trade Commission, 1966:26-27). Firestone’s archival records, for example, demonstrate that company lost money on its OEM business in three of the five years between 1969 and 1972, for a cumulative loss of $11 million before depreciation or overhead costs (Firestone Minutes of the Board, 1969-1972). Nor was it clear that OEM business contributed to increased sales in the more profitable replacement market. Repeated market surveys demonstrated that replacement purchases were virtually unaffected by the brand of tires initially installed on a car (Politz, 1968). Despite the low profits, Akron-based executives continued to believe that OEM sales were critical.

The Akron competitors also apparently shared the assumption that technical competition hinged on incremental extensions to the bias belted tire that had emerged as the industry’s dominant design by the 1930s and persisted through the 1960s. Warner (1966:276-277) identifies an average of one design innovation per year for the period between 1940 and 1965, but each of these were incremental extensions of the bias ply tire, such as changes in the tire’s diameter, tread design and fabric ply composition, and many of these innovations were merely cosmetic--e.g., raised white letters. The Akron-based firms closely monitored one another’s major research initiatives, created parallel programs and quickly responded to local competitors’ innovations (Warner, 1966:232).

Technical Change and Inertia: 1965-1988

By the mid-1960s, the U.S. tire companies were faced with an alternative tire design--the radial tire --that had been pioneered by French tire maker Michelin immediately after the Second World War. The radial tire, which reinforced the tire’s plies with steel wire, increased the tire’s useful life from 20,000 to 40,000 miles, reduced a driver’s gasoline consumption by 5-10%, improved handling and dramatically reduced the likelihood of a catastrophic tire failure, known as a “blowout.” Michelin leveraged its lead in radial product and process technology to increase its share of the major European tire markets from under 10% in the early 1960s to nearly 30% by 1972 (Harkelroad, 1978). Between 1960 and 1972, Michelin build 26 greenfield radial tire factories, 14 of which were outside France (Harkelroad, 1978:10). Incumbent tire makers in Europe embarked on a crash course to adopt radial tire technology, but could not close the technical gap quickly enough to halt their relative decline. The Akron tire companies witnessed Michelin’s success firsthand. Goodyear, Firestone and B.F. Goodrich had all operated in Europe since the 1920s, and the leading

U.S. tire producers together owned 29 factories in Europe, placing them among the 10 largest European tire companies (Harkelroad, 1978:6, 17).

By the mid-1960s, several prominent events signaled that the radial tire had entered the U.S. market. Michelin agreed to manufacture passenger radial tires for Sears in 1966, and announced construction of its first North American radial tire plant three years later (van der Poel, 1982). In the mid-1960s, B.F. Goodrich introduced the first American-made radial tire in an attempt to gain market share from its larger rivals in the tire industry (Blackford & Kerr, 1996:276-278). The August 1968 *Consumer Reports* awarded its top two spots to radial tires and documented the new technology's longer life, increased safety, handling and economy relative to bias tires. (Consumer Reports, 1968).

The Akron-based tire companies did not ignore the radial tire, nor did they respond slowly. Rather, they responded to the new technology quickly, but did so in a manner consistent with the models of competition prevailing within Akron. Goodyear responded to the radial tire in 1967 by further extending the core bias tire design with its introduction of the belted bias tire (O'Reilly, 1983:156). The belted bias tire featured a strip or "belt" of polyester fiber or fiberglass that ran along the tire tread, and represented only a slight modification to the traditional bias design (Kovac, 1978). Although the belted bias only incrementally extended the existing tire design, Goodyear aggressively promoted it as an alternative to radials and claimed significant performance improvements (Denoual, 1980:279). The other leading tire companies quickly followed Goodyear's lead and introduced belted bias offerings of their own. Firestone's Research and Development Group, for example, matched Goodyear's belted bias tire within a few months and developed a second-generation belted-bias tire within one year (Sull, 1999:441). The belted bias tire won rapid acceptance among automobile OEMs and end-users, and accounted for more than one-half of all tire shipments by 1971 (Figure 4).

INSERT FIGURE 4 ABOUT HERE

Although belted-bias tires initially gained significant market share, they provided few tangible benefits to consumers and quickly fell out of favor with OEMs and end-users. In a 1971 *Consumer Reports* evaluation, five of the seven belted-bias tires failed at high-speed and tread-life tests and underperformed bias tires in safety, cost effectiveness and handling (Consumer Reports, 1971). The OEMs were actively evaluating radials as an alternative to belted-bias tires, and a 1971 internal study by General Motors concluded that radial technology conferred compelling advantages to both the automobile manufacturers and end users, and the company formed a central Tire Group to persuade the U.S. tire manufacturers to develop radial tires. In 1972, General Motors announced its intention to place radial tires on all models over the next few years, following a similar decision that Ford made a few months earlier (Denoual, 1980:20). Although tire executives were well aware of the OEMs interest in radials, they had apparently expected a more gradual transition and were caught off guard by the abruptness of General Motors' and Ford's decision and the planned pace of radial adoption (Denoual, 1980:206).

Once the major OEMs switched, both the ultimate level and pace of radial adoption were very predictable. The tire manufacturers, which accounted for approximately one-third of the market, essentially dictated their planned radial placements to the suppliers. Replacement market penetration was also highly predictable based on the rapid and similar radial diffusion patterns across several European countries in which Michelin had introduced the radial (Sull et al., 1997;475). The financial consequences of widespread radial adoption were also predictable and extremely unattractive. In the early 1970s, tire executives estimated that converting existing bias manufacturing capacity to radial production would require industry-wide capital expenditure of $600 to $900 million (Rowand, 1971:56; LaFerre, 1972:51). Because radials lasted approximately twice as long as the bias tires they replaced, their adoption would trigger a reduction in the number of tires sold into the replacement market and increase the tire manufacturers' reliance on the less profitable OEM market. Nor could the tire makers expect to charge a price premium on radial tires sufficient to offset their large capital expenditure and lost unit volume. Non-U.S. producers appeared willing to sacrifice profits to gain market share (Consumer Reports, 1971:476), and in 1971, the price of the average radial tire was 31% lower in nominal dollars than in 1968. Institutional investors recognized the financial implication of radial tire adoption, and sold off large blocks of tire company stocks (Value Line, 1972:169).

Faced with the prospect of predictable radial adoption and its adverse financial implications, the tire manufacturers might have reevaluated the long-standing reliance on the OEM market. In 1969, B.F. Goodrich held secret meetings with Francois Michelin to discuss a possible joint venture in which the French tire company would manufacture radial tires for sale to Goodrich's OEM clients (Blackford & Kerr, 1996:278-279). When the talks with Michelin failed to result in a joint venture, B.F. Goodrich considered exiting the OEM business, and ultimately did. The U.S. tire makers might also have attempted to shift a portion of the financial burden for converting to radial production to the automobile manufacturers by making investment in radial capacity contingent upon price guarantees, for instance. Instead, Goodyear, Firestone and General Tire embarked on a crash course to build radial production capacity to serve the OEMs, investing $950 million of capital spending in excess of depreciation in their tire operations between 1972 and 1974 (Sull et al., 1997:479).

Interviews with the former CEOs of Goodyear (Pilliod, 1995) and General Tire (O'Neil, 1994) suggest that these companies invested in radials without examining their long-standing belief in the importance of OEM customers, and an analysis of Firestone's archival records demonstrates this was the case for Firestone (Sull, 1999:442-443). When Firestone's Executive Committee--which was responsible for evaluating and approving all capital budgeting decisions--met in November of 1972, the members learned that marketing managers had already promised radial tires to Ford and General Motors for the following year. The committee authorized the vice president of manufacturing to place orders for long-lead-time equipment necessary to manufacture the radial tires and bring the formal request as soon as possible, thereby authorizing the expenditure before reviewing the formal proposal. When the committee met the following month to discuss the formal proposal, the entire discussion focused on the details of implementation, such as optimal plant location, rather than a discussion of the soundness of investing so heavily in radial production to serve unprofitable OEM customers. The decision was made despite forecast returns on investment that were below the tire business' hurdle rate of 8 to 10% and the 28% average return on investment the company earned in its non-tire businesses, which included steel wheels, seat belts and foam rubber.

Although the tire manufacturers invested heavily and quickly once the OEMs switched to radials, they delayed closing the bias tire plants rendered unnecessary by their investment in the new technology. Radial tires lasted approximately twice as long as the bias and bias-belted tires they replaced, which implied that incumbent tire makers would need to close approximately one-half of their existing factories to align production with demand. The tire manufacturers did ultimately close 29 of the 57 passenger tire factories operating in the United States in 1972, but they dragged these closures out over a decade. Delays in closing redundant bias factories depressed industry-wide capacity utilization to 46 to 65% and triggered a price war that drove the price of bias tires to within one dollar of their variable cost (Firestone Minutes of the Board, March 13, 1980: Exhibit 11).

The combination of low prices and low capacity utilization severely depressed bias factories' operating profits prior to their ultimate closure. Given the foreseeable decline in bias demand and industry-wide overcapacity, there was no plausible argument for firms to keep plants open after they began incurring operating losses. Yet the five large U.S. tire companies appear to have delayed closing their bias-tire factories at great economic cost. Table 8 reports estimates of the financial costs resulting from delays in closing bias plants, where a delay is measured as the time elapsed in years between the first year a factory experiences a negative operating profit and the year in which the factory was ultimately closed.[2] The five largest tire companies closed 20 bias factories between 1972 and 1987 (smaller competitors accounted for the other nine plant closures). No tire plant in the sample was closed the first year it lost money, and the average delay ranged from 1.8 years for Goodyear to 6.0 years for General Tire. The total pre-tax losses incurred by delays in closing all 20 tire factories totaled $1,080 million, which exceeded one-third of the combined market capitalization of the five large tire companies in 1974.

INSERT TABLE 8 ABOUT HERE

Part of the explanation for tire companies' delays in closing factories may lie in executives' taken-for-granted assumption that tires was a growth industry that required capacity additions. Figure 5 plots the Rubber Manufacturers' Association's forecasts made in the years 1971 through 1972 (as well as actual tire shipments between 1970 and 1977). The forecasts made in 1971 are fairly close to actual shipments in 1972 and appear to extrapolate historical demand for the following three years. Forecasts made in November of 1972 occurred after the OEMs decision to switch to radials but do not appear to reflect the decreased demand resulting from radial adoption. While the 1973 and 1974 forecasts steadily reduce forecast demand, it is not until 1975, three years after the OEMs announced their intention to switch to radials, that the forecasts began to approach actual shipments again. The belief that tires was a growth industry apparently influenced the thinking of Firestone president Richard Riley, who listed growth as the company's primary objective in six of his seven annual addresses to shareholders between 1972 and 1979, although he confided to his board that he "felt somewhat uncomfortable" trying to reconcile his growth projections with market realities in the wake of the radial tire (Sull, 1999:446).

INSERT FIGURE 5 ABOUT HERE

[2] To estimate these losses, I calculated annual plant-level cash profitability (defined as plant-level revenues less the factory's direct and indirect labor expenses, raw material costs and facility overhead) for every U.S. tire factory between 1974 and 1987. The Rubber Manufacturers' Association provided annual plant-level capacity and the individual tire companies provided data on each factory's annual product mix and level of capacity utilization. The National Tire and Retreader Association provided a data series on annual mean wholesale tire prices based on a national survey. The United Rubber Workers provided annual data on the numbers of employees, hours worked and hourly wage and benefit costs for each factory. Firms supplying materials accounting for 95% of a tire's material costs furnished historical prices to the tire industry. Plant-level overhead costs were calculated based on corporate archival data while tax, insurance and utility costs were gathered from corporate and governmental data sources.

While Firestone, Goodyear and General Tire responded to radial technology by initially promoting the belted-bias tire then investing in radial capacity to meet OEM's demand and delaying closure of unnecessary bias factories, B.F. Goodrich responded to the radial tire very differently from its Akron-based competitors. In 1969, B.F. Goodrich was the target of a hostile takeover led by Ben Heinemann (Blackford & Kerr, 1996:290-292). While Goodrich management successfully defended the company against the hostile takeover bid, the board lost confidence in the CEO and replaced him with an oil industry executive from Texas. The new CEO tapped outsiders to staff his management team, and by 1972, fewer than one-half of the B.F. Goodrich executives had spent their entire careers in the company and none were Akron natives or veterans of the domestic tire business (Table 6).

The B.F. Goodrich top management team responded very differently than the executives at the other Akron-based tire companies (Sull, 1999:455-459). Goodrich executives did invest in converting bias capacity to radial production, but they carefully monitored the financial returns on their investment and, alone among the major tire companies, avoided the investment in a greenfield radial tire factory. B.F. Goodrich was also the most aggressive competitor in closing plants, closing two bias tire plants in 1975 (two years before any of the other majors closed plants) and incurred the smallest average loss from delay in plant closures of any tire company (Table 8). While the other tire companies aggressively pursued OEM business, B.F. Goodrich focused on the more profitable replacement business, and in 1981, took the dramatic steps of exiting the OEM business altogether, although automobile manufacturers accounted for 10% of sales. The Goodrich management ultimately adopted an explicit strategy to milk the tire division and invest only as much as was necessary to maintain the tire operations as an attractive acquisition candidate for another tire company.

DISCUSSION

The findings from a historical analysis of the U.S. tire industry from 1900 to 1990 suggest that the firms clustered in Akron initially led the industry in innovation, but later failed to respond effectively to the introduction of radial tire technology. To understand why the Akron cluster evolved, it is helpful to disentangle two distinct consequences of the geographic co-location of competitors in the same industry. Geographic co-location increases the ease with which "communities of practice" can form, and these tightly interwoven social and professional networks provide the conduits through which tacit knowledge flows. These knowledge flows, in turn, contribute to cumulative incremental innovations in both product and process technology among firms embedded in the cluster. The benefits of this knowledge sharing, however, are likely to decline over time as the industry settles on a dominant design and converges on the optimal production process. While the knowledge sharing benefits of clusters takes off, the liability of institutionalization rise steadily as a function of time (Figure 6). These costs consist primarily of foregone flexibility resulting from persistence of established behaviors and taken-for-granted assumptions that may outlive their usefulness as the competitive environment changes (Zucker, 1977), leaving the firms within the cluster susceptible to an environmental jolt (Pouder & St. John, 1996).

INSERT FIGURE 6 ABOUT HERE

The findings from the study also contributes to our understanding of organizational inertia. Hannan & Freeman (1984:151) define inertia in terms of the relative speed of adaptation and argue that organizations suffer inertia when they fail to change as quickly as the environment. Although the tire firms delayed closing redundant capacity, they responded fairly quickly to the introduction of radial tires by extending bias technology with the belted bias tire. The tire firms also invested rapidly to build radial tire production capacity once the OEMs switched to the new technology. In the case of investment in radial manufacturing capacity, the tire firms may have actually acted too hastily, given the high capital investment costs and predictably low return. The tire companies did not respond to radial technology by doing nothing or by delaying necessary actions, but rather responded by accelerating activities--such as incremental extensions of the existing product and building new plants--that had worked in the past and were based on assumptions that had at one point been consistent with the competitive environment. I use the term “active inertia” to describe the tendency of firms to respond to changes in their competitive environment not by doing nothing, but by accelerating past organizational routines based on established assumptions.

The tire industry data also provide insights into the micro-processes that contribute to inertia. Taken-for-granted shared assumptions about the industry were enacted through established organizational routines, and these assumptions and routines mutually reinforced one another (Barley & Tolbert, 1997). Tire executives apparently assumed that the bias tire would continue as the dominant design, and this assumption was enacted through their company’s well-honed new product development process which had produced a steady flow of incremental extensions to the dominant design throughout the preceding decades. Similarly, the assumption that tires was a growth industry was enacted through the capital budgeting process that resulted in a steady stream of new factories being built to meet rising demand. When faced with the radial technology, executives responded with investments in new plants that resulted from their well-honed capital budgeting process and was consistent with their assumption that tires was a growth industry. Because none of the four Akron tire companies had closed a factory prior to 1975, these firms lacked a process for disinvestment, and their capital budgeting process stalled in reverse.

This study suggests opportunities for future empirical research. Future studies could analyze the evolution of once-comparable clusters such as the financial centers in Paris and London or shoemaking districts in different regions of Italy. Comparative historical case analysis could also explore how differing trajectories of technological development influence the evolution of industrial clusters. It would also be interesting to chart the attempts by many regional development boards and business associations to capture the benefits of clustering by imitating Silicon Valley. A broader extension of this study would explore how various contexts contribute to entrepreneurship and innovation, and compare industrial clusters with other possible contexts, such as incubators or large corporations. Future clinical research could compare, for example, similar entrepreneurial ventures within an industrial cluster, an incubator, and a large corporation to understand how each context promoted or hindered the venture. An empirical study might categorize different contexts and analyze how they contribute to survival rates. Future theoretical research could elaborate the dimensions along which contexts for entrepreneurship vary and how these contribute to or hinder the pursuit of opportunity.

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Table 1
Overview of Archival Data Sources

Organization	Description	Time period covered	Access
Firestone Tire & Rubber	Akron-based tire manufacturer	1900-1987	Full
Goodyear Tire & Rubber	Akron-based tire manufacturer	1970-1995	Partial
B. F. Goodrich	Akron-based tire manufacturer	1898-present	Full
General Tire	Akron-based tire manufacturer	1965-1985	Partial
Akron Beacon Journal	Local daily newspaper	1905-present	Full
United Rubber Workers	Labor union representing tire worker	1930-present	Full
University of Akron	Archives focused on tire industry history	1890-present	Full
Smithers Scientific	Largest tire technical testing service	1925-present	Full

Figure 1
Time-ordered matrix for Akron tire cluster: 1900-1988

Era	**Clustered innovation**	**Institutionalization**	**Active inertia**
Years	1900-1935	1935-1965	1965-1988
Industry characteristics			
number of firms	peaks at 190-274	stable at approximately 25-35	further reduction in number of firms
entry	concentrated 1900-1927	no entry by domestic competitors	entry of non-US firms
exit	concentrated 1922-1930	slow decline in number of small firms	four of "Big Five" firms exit
market share of four largest firms	grows to 80% by 1935	stable at 70-80% throughout era	declines in face of non-US firms
Technology			
manufacturing process	dramatic improvements	stabilized over this period	disrupted by radial technology
product design	experiments until dominant design	refine dominant design	disrupted by radial technology
Competition			
model of industry growth	high growth	assumption of growth institutionalized	growth assumed despite radials
investment in manufacturing capacity	expand factories in Akron	accelerate investment in new plants	heavy investment in radial capacity
plant closure	no plants closed in this period	no plants closed in this period	costly delays in plant closures
importance of automobile OEM customers	critical to growth	considered critical although unprofitable	considered critical
Akron community			
population	rapid growth (42,728 to 255,045)	slow growth (255,045 to 349,000)	decline
residential neighborhoods	tire executives move to West Akron	tire executives remain concentrated	tire executives remain concentrated
Portage Country Club	attracts tire industry executives	tire executives dominate club	decline in membership

Table 2
Estimates of total firms, entries and exits by year: 1914-1937

	Estimates of firms from French (1986)			Estimates of firms from Thomas Register		
	Total number of firms	Number of firms entering	Number of firms exiting	Total number of firms	Number of firms entering	Number of firms exiting
1914				90	45	11
1915				98	17	9
1916				118	30	11
1917				128	24	9
1918				142	31	17
1919	190	44	1	n.a.	n.a.	n.a.
1920		16	2	179	57	16
1921		16	9	198	28	10
1922	166	11	16	274	137	65
1923	129	9	29	245	39	65
1924	111	4	22	208	23	55
1925	97	7	18	185	20	47
1926	93	1	20	163	8	30
1927	92	0	13	122	17	52
1928	78	2	18	131	6	1
1929	62	0	19	120	0	17
1930	50	0	11	96	2	26
1931		0	11	81	1	19
1932		0	3	65	4	22
1933	35	0	2	n.a.	n.a.	n.a.
1934		0		63	4	6
1935		0	2	62	3	5
1936		0	6	57	2	7
1937		0	3	53	5	10

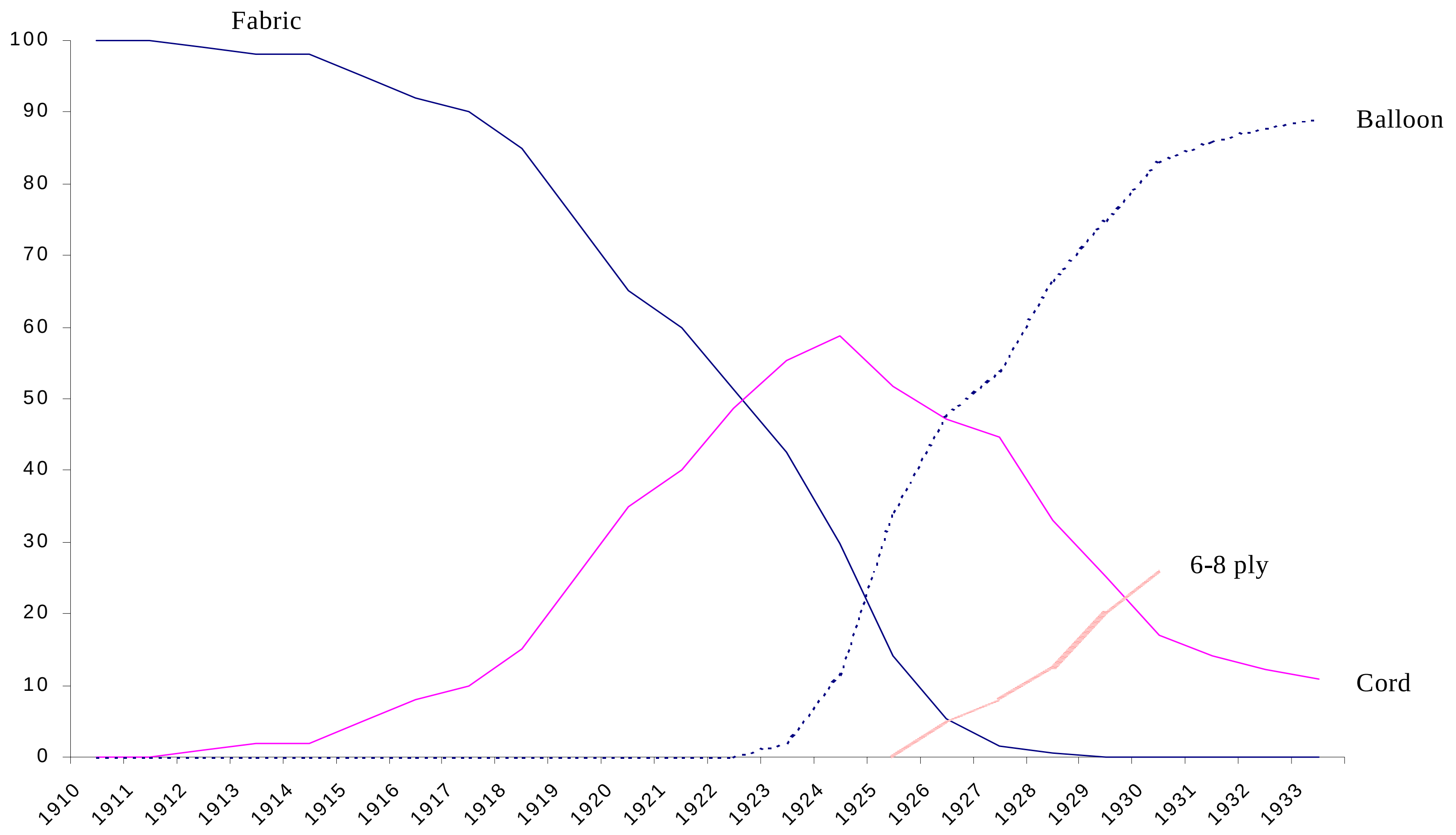
Note: Thomas Register of American Manufacturers was not published in 1919 and 1933

Table 3
Rank among U.S. firms (by assets) and market share of four largest tire firms: Selected years 1909 through 1964

		1909	1917	1919	1929	1930	1935	1948	1958	1964
Rank among U.S. tire firms by assets										
	Goodyear		3	3	2	1	1	1	1	1
	Firestone		4	4	4	4	3	3	2	2
	U.S. Rubber	1	1	1	1	2	2	2	3	3
	B. F. Goodrich	2	2	2	3	3	4	4	4	4
	Fisk Rubber Co.		5	5	5	5				
	General Tire							5	5	5
Rank among all U.S. firms by assets										
	Goodyear	n.a.	54	51	33	37	35	32	26	28
	Firestone	n.a.	81	87	63	61	60	38	39	34
	U.S. Rubber	11	9	8	27	43	52	37	56	62
	B. F. Goodrich	25	22	24	60	56	65	62	68	72
	Fisk Rubber Co.		107			137				
	General Tire							188		
Share of U.S. tire market										
	Four largest firms	n.a.	n.a.	55%	n.a.	n.a.	80%	77%	74%	70%
	Eight largest firms	n.a.	n.a.	n.a.	n.a.	n.a.	90%	90%	88%	89%

Figure 2

Percentage of U.S. Passenger tire shipments by construction type: 1910-1933



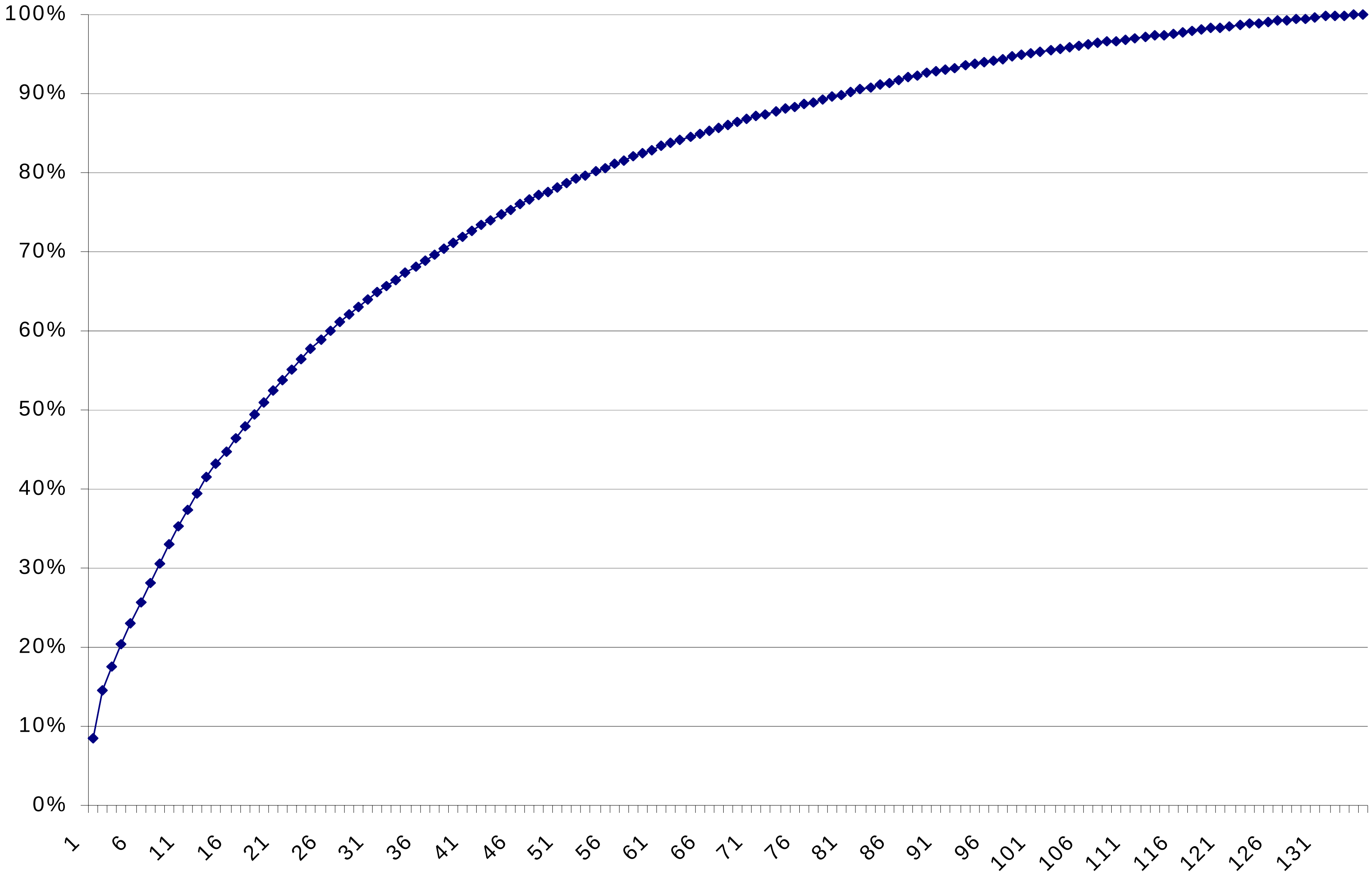
Source: Gaffey, 1940:43; Fraser & Doriot, 1932:103.

Table 4
Summary of major tire innovations by category and innovator(s): 1899-1939

	Innovator	tire firm	Akron based	Innovator	tire firm	Akron based
Tire construction and rim design						
fabric tire	unknown					
1899 clincher tire	North British	X				
1903 Universal rim	Goodyear	X	X			
1905 straight-side tire	Firestone	X	X	Goodyear	X	X
1906 reversible flange rim	Firestone	X	X			
1908 diamond tread	Goodyear	X	X			
1910 cord tire	Diamond	X	X			
1912 multiple-ply cord tire	Goodyear	X	X			
1922 balloon tire	Firestone	X	X			
1925 6-8 ply tires (vs 4 ply)	Goodyear	X	X			
1927 white sidewall	unknown					
Raw materials and tire components						
1899 reclaim rubber	Diamond	X	X			
1899-1905 long-staple cotton	unknown					
1900 braided wire	Goodyear	X	X			
1905 gas blacks	Diamond	X	X			
1906 organic accelerators	Diamond	X	X			
1912 carbon black	Diamond	X	X	Goodrich	X	X
1912-1923 improved organic accelerators	Goodrich	X	X	American Cyanamid		
1920 Captex (organic accelerator)	Goodyear	X	X			
1922 furnace blacks	Columbian					
1922 aldehyde (antioxidant)	U.S. Rubber	X				
1923 first-order high-twist cotton	Goodyear	X	X			
1924 aromatics (antioxidants)	Goodrich	X	X	Du Pont		
1926 crack resistant antioxidants	Du Pont					
1931 rayon stretch spinning	Rayon Co.					
1935 high tenacity rayon	Du Pont					
1936 second-order high-twist cotton	Lee-Goodrich					
1937 rayon cord passenger tires	Goodrich	X	X	Goodyear	X	X
1938 N-type synthetic rubber	Goodyear	X	X			
1939 S-type synthetic rubber	Goodrich	X	X			

Sources: Warner, 1966:268-270; Gaffey, 1940:44-48; O'Reilly, 1983:19-26; Blackford & Kerr, 1996:66,88.

Figure 3
Cumulative percentage of total labor productivity increase resulting from 135 tire industry process innovations



Source: Stern, 1933

Table 5
Profile of Portage Country Club members in 1906

	founder	technical executive	other executive	investor	total
B. F. Goodrich	0	3	7	2	12
Goodyear	2	2	3	3	10
Firestone	1	1	1	1	4
Diamond Tire	1	1	1		3
Total	4	7	12	6	29
Total members					150

Source: Zensius, 1994.

Table 6
Profile of Top Management Teams in the Big Five Tire Companies in 1972

	Goodyear	Firestone	Uniroyal	BFGoodrich	General
Number of executives in top management team	6	6	5	7	6
Percentage of top executives who spent their entire career in the company	67%	100%	100%	43%	100%
Percentage of top executives who were born and raised in Akron	33%	67%	n.m.	0%	50%
Percentage of top executives who whose fathers worked for the same tire company	0%	33%	0%	0%	50%
Percentage of top executives who rose through the domestic tire division	50%	50%	20%	0%	33%

Table 7
New plant construction by location: 1919-1982

	Goodyear	Firestone	B. F. Goodrich	General Tire	:	U.S. Rubber	Michelin
1919					:		
1920	Los Angeles				:		
1921					:		
1922		Los Angeles	Los Angeles		:		
1923					:		
1924					:		
1925					:		
1926					:		
1927					:		
1928					:		
1929					:		
1930					:	Los Angeles (acquired)	
1931					:		
1932					:		
1933					:		
1934					:		
1935					:		
1936					:		
1937	Jackson, MI	Memphis, TN	Oaks, PA		:		
1938					:		
1939					:		
1940					:		
1941					:		
1942					:		
1943					:		
1944				Waco, TX	:		
1945	Topeka, KS	Des Moines, IA	Miami, OK		:		
1946			Tuscaloosa, AL		:		
1947					:		
1948					:		
1949					:		
1950					:		
1951					:		
1952					:		
1953					:		
1954					:		
1955					:		
1956					:		
1957					:		
1958					:		
1959					:		
1960		Salinas, CA		Mayfield, KY	:		
1961					:		
1962	Tyler, TX		Ft. Wayne, IN		:		
1963	Freeport, IL	Decatur, IL			:	Opelika, AL	
1964					:		
1965		Bloomington, IL			:		
1966	Danville, VA				:		
1967				Charlotte, NC	:		
				Bryan, OH	:		
1968	Union City, TN	Albany, GA			:		
1969		Oklahoma City, OK			:		Nova Scotia, CN
		Fayetteville, NC			:		
1970					:	Ardmore, OK	
1971					:		Nova Scotia, CN
1972	Madisonville, KY	Nashville, TN			:		
1973					:		
1974		Wilson, NC		Mt. Vernon, IL	:		
1975					:		
1976					:		
1977					:		Greenville, SC
1978	Lawton, OK				:		Spartanburg, SC
	Gadsden, AL				:		Dothan, AL
1979					:		
1980					:		
1981					:		Lexington, SC
1982					:		Lubbock, TX

Source: United Rubber Workers, 1980.

Figure 4
Percentage of tires shipped by construction type: 1961-1987

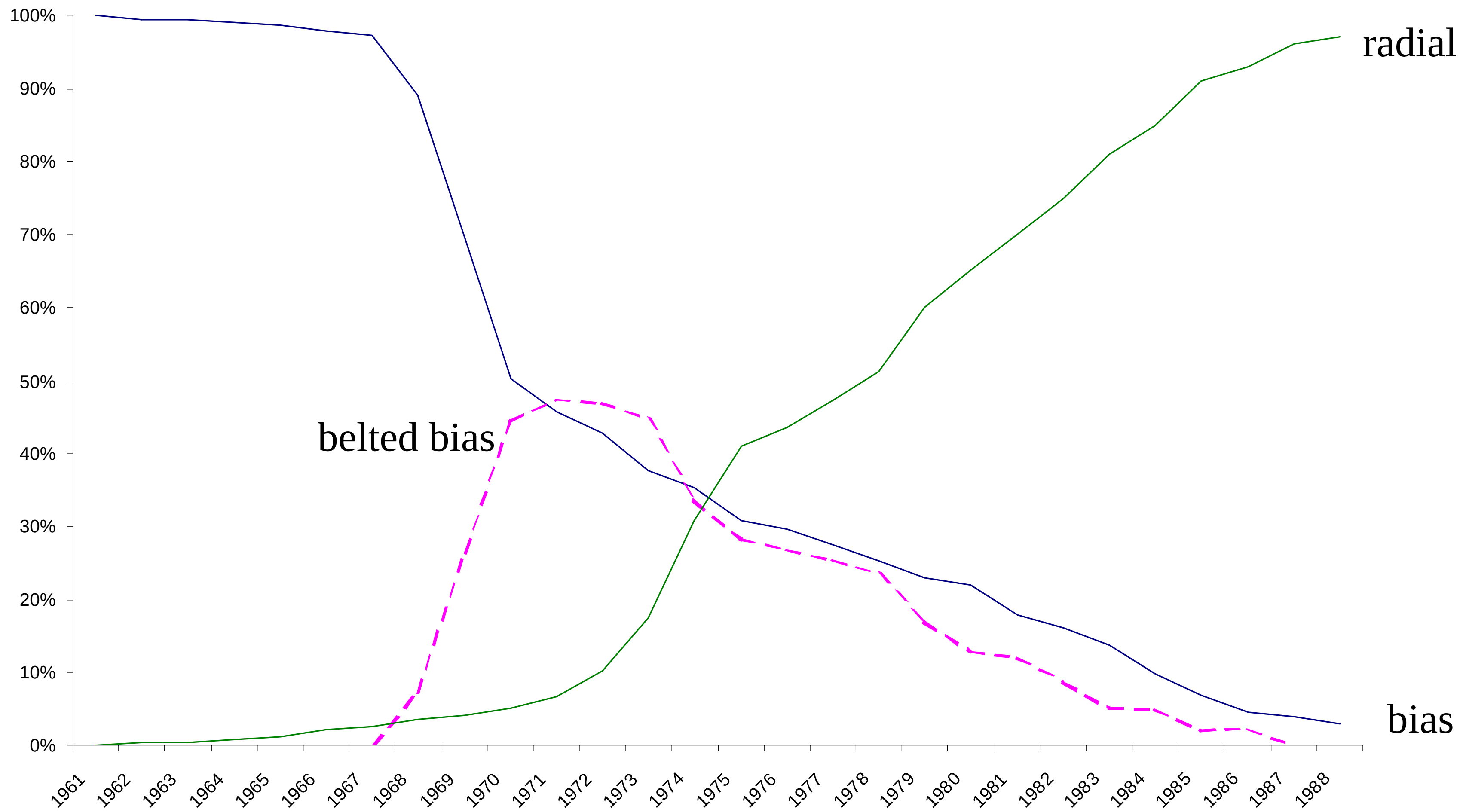
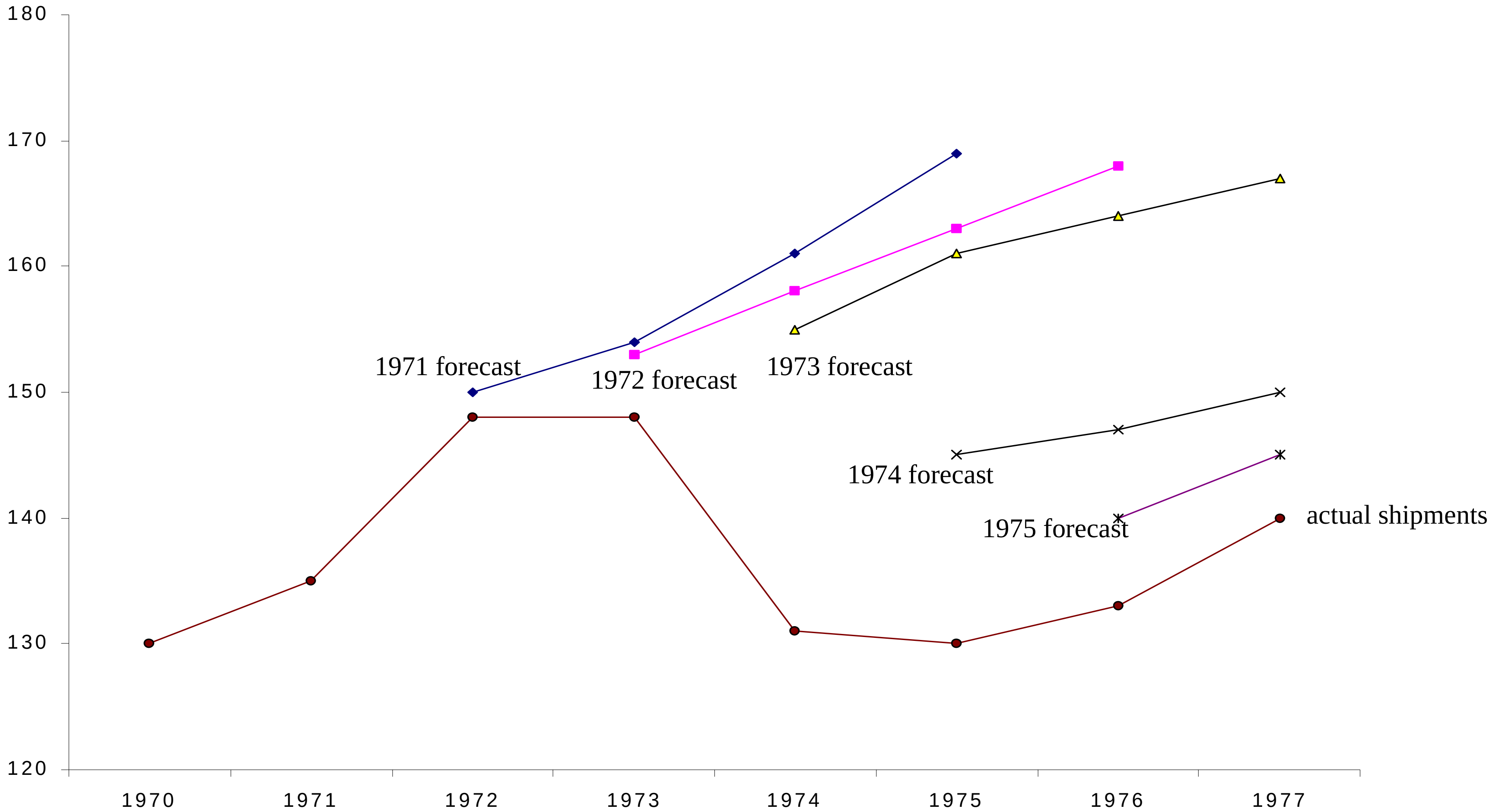


Table 8
Measures of tire firms delay in disinvestment from bias tire technology

	Passenger tire plants operating in 1972	Passenger tire plants closed 1972-1987	Closed tire plants as a percentage of starting	Total cumulative losses from delaying all plant closures (nominal $ million)	Average cumulative losses from delaying plant closures (nominal $ million)	average delay in plant closure (years)	year firm closed first plant
Goodyear	12	(5)	42%	($221)	($44)	1.8	1977
Firestone	11	(8)	73%	($355)	($51)	3.4	1978
Uniroyal	6	(2)	33%	($262)	($87)	3.3	1978
Goodrich	6	(4)	67%	($149)	($37)	2.3	1975
General	5	(1)	20%	($93)	($93)	6.0	1986

Figure 5
Rubber Manufacturers' Association consensus forecasts of aggregate passenger tire demand: 1969-1973



Source: Shleifer, 1981: Exhibit 12.

Figure 6

Conceptual model of cluster evolution