Dominance by Birthright:

Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry

Steven Klepper, Carnegie Mellon University

Kenneth L. Simons, Royal Holloway, University of London

This is a preprint of an article published in *Strategic Management Journal*, vol. 21 no. 10-11 (October-November), 2000, pp. 997-1016. Wiley web site.

1999

Date of this version: December 1999

Steven Klepper
Dept. of Social & Decision Sciences
Carnegie Mellon University
Pittsburgh, PA 15213
USA

phone +1 412 268 3235
fax +1 412 268 6938
email sk3f@andrew.cmu.edu

Kenneth L. Simons
Dept. of Economics
Royal Holloway College
University of London
Egham, Surrey TW20 0EX
UK

phone +44 1784 443909
fax +44 1784 439534
email K.Simons@rhul.ac.uk

Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry

Steven Klepper and Kenneth L. Simons[†]

I. Introduction

Entry plays a central role in nearly all industry economists' models of industrial competition. Equilibrium is assumed to be brought about by a pool of potential entrants, ready to enter if incumbent firms earn excessive profits. If an unlimited pool of such potential entrants, each with capabilities comparable to incumbent firms, is assumed to exist, then in the long run economic profits are driven to zero. Where these firms come from and where they get their capabilities is not generally considered in such models; all that is important is that a sufficient number of them exist to drive economic profits to zero. This perspective stands in sharp contrast to the business strategist's conception of industrial competition. Strategists assume that firms are fundamentally different. They exhort firms to identify and exploit their core capabilities, which can be the source of persistent economic profits. But where do these capabilities come from? Do firms possess them when they initially enter industries? If so, then entrants will differ in the threat they pose to incumbents, and entry will no longer insure that economic profits are driven to zero over time. Indeed, the very notion of an equilibrium in which all firms earn zero economic profits would no longer be so compelling.

In light of the importance of entry in models of industrial competition, it is surprising how little industry economists and strategists know about where entrants come

[†] We thank Keith Pavitt, Richard Rosenbloom, and participants in the 1999 Dartmouth Conference on the Evolution of Firm Capabilities. Klepper gratefully acknowledges support from the Economics Program of the National Science Foundation, Grant No. SBR-9600041.

from and how their backgrounds affect their fates. The few studies that consider all the entrants into an industry and analyze how their backgrounds affect their market share and survival over the industry's evolution are not reassuring about conventional models. They suggest that firm histories do have a substantial effect on firm performance (Lane [1989], Mitchell [1991], Carroll et al. [1996]). Whether the effects of pre-entry experience dissipate or persist over time and exactly how the backgrounds of entrants condition their performance is less clear. Even less is known about what effect, if any, heterogeneity among entrants has on the nature of competition and the market structure of industries.

This paper explores how prior experience conditions entry, firm performance, and the evolution of market structure in one industry, television receivers, where considerable information could be collected about an important class of potential entrants—firms that produced radios prior to the start of the tv receiver industry. This is a particularly interesting group of firms because radio producers dominated the tv industry even though they accounted for a minority of entrants. Moreover, the tv receiver industry has drawn a lot of attention from researchers, particularly doctoral students, due to the sharp shakeout of producers it experienced and the eventual demise of all U.S. tv producers when the industry was besieged by international competition (Datta [1971], Levy [1981], Willard [1982], LaFrance [1985], Wooster [1986]). This has left in its wake considerable information to draw upon to understand the nature of competition in the industry and to analyze how the background of entrants affected their performance and the evolution of the industry.

We exploit various sources to construct a comprehensive data base on tv and radio producers. We identify every producer of televisions, its date of entry and exit, any ownership changes it underwent, and its periodic market share. We compile a list of all firms that produced radios in the few years before the start of the television industry. For each, we determine the number of years it produced radios, its size, the type of radios it produced, and whether it entered the tv receiver industry. This enables us to analyze how radio producers' backgrounds affected entry into the tv industry and the extent of heterogeneity among the radio entrants. We also use the information to analyze how experience in radios affected firm market shares and firm exit rates over the different eras of competition in the tv industry. Furthermore, we exploit a list of major tv product innovations and construct a list of early tv process innovations to explore the pathways by which radio experience influenced firm performance.

A model of the evolution of a new industry developed by Klepper [1996, 1999] is used to generate hypotheses concerning how radio experience conditioned entry, firm performance, and the evolution of market structure in the tv industry. The model emphasizes the role of innovation and heterogeneity among entrants in contributing to a shakeout and the evolution of an oligopolistic market structure. Firms with more relevant experience are conjectured to have superior abilities to manage R&D in the new industry. This provides them with a competitive advantage that persists over time due to a process of increasing returns that enables the most qualified early entrants to dominate the new industry. R&D is the source of the increasing returns because larger firms have greater output over which they can apply, and thus profit from, their innovations. The model yields a number of implications about how pre-entry experience affects entry and firm performance that we use to structure our empirical analysis. We also use the model to speculate on how the pre-entry characteristics of the most successful television producers made the industry ultimately so vulnerable to international competition.

Our findings indicate that among firms producing radios, those with the most relevant experience entered the television industry. On average, these firms entered earlier, survived longer, and had larger market shares than nonradio producers. Indeed, no nonradio producer ever captured a significant share of the television market. Not only did the radio firms have distinctive advantages over the other entrants, but among these firms the larger ones survived longer and captured a greater share of the market. The hazard rates of the radio producers, especially the larger ones, were not only lower during the early years of the industry but also when the pace of technological change picked up during the commercialization of color television and later when the industry was besieged by international competition. The model implicates innovation as the source of the persistent advantage of the radio firms. Consistent with the model, our findings indicate that nonradio entrants did little innovation and the larger radio producers thoroughly dominated both product and process innovation, which appears to have contributed significantly to their greater longevity and ultimate dominance of the U.S. industry.

The paper is organized as follows. In Section 2 we review the evolution of competition in the television set industry, focusing especially on the role played by the radio producers. In Section 3 we use the model of industry evolution to structure how pre-entry radio experience is expected to influence firm entry, innovation, survival, and market structure. In Section 4 we present the empirical analysis. In Section 5 we discuss alternative explanations for our findings and speculate on why the leading U.S. producers of televisions proved so vulnerable to international competition. We also consider the extent to which other industries have evolved similarly to televisions and the implications of our findings for modeling competition in new industries. In Section 6, we offer concluding remarks.

II. Radio Producers and the Evolution of the Television Receiver Industry[1]

While many individuals contributed to the development of television, Vladimir Zworykin and Philo Farnsworth are the acknowledged pioneers of the industry. Zworykin began his research in the U.S. at Westinghouse and continued it at RCA when RCA took over the radio research of GE and Westinghouse, two of its parents. By the late 1930s RCA had developed a commercially viable monochrome television system on which it had taken out many patents. Farnsworth's work was initially privately financed, and later Farnsworth Television and Radio Corporation was formed to exploit Farnsworth's patents and to produce radios.

Technical standards for monochrome broadcasting were agreed to by the emerging industry and adopted by the Federal Communications Commission (FCC) in 1941, but World War II delayed commercial broadcasting and the sale of receivers until 1946. Subsequently RCA and CBS engaged in a battle over color broadcasting standards that was eventually won by RCA in 1953. Demand for television receivers was great after World War II, and annual sales of monochrome receivers reached nearly 3 million sets in 1949 and over 7 million sets in 1950. As an increasing fraction of U.S. homes

[1] The main sources used to compile the information in this section are MacLaurin [1949], Datta [1971], Levy [1981], Willard [1982], and Wooster [1986].

were equipped with television sets, annual sales of monochrome receivers did not subsequently rise much above 7 million sets. Color receivers were introduced in 1954, but their high price, poor quality, and limited color broadcasts kept sales down until 1964, when approximately 1.4 million color sets were sold. Subsequently color sales increased sharply to nearly 6 million sets in 1968, after which growth slowed as sales rose to approximately 11 million sets in 1980.

A flood of firms entered the industry after commercial broadcasting began, similar to the radio receiver industry following the craze that broke out after the initiation of radio broadcasting by Westinghouse and the *Detroit Daily News* in 1920. The annual number of entrants, exits, and firms over the period 1947-1989 based on periodic listings in the trade publication *Television Factbook* is plotted in Figure 1.[2] In 1947, 31 firms were listed as producers. Entry was rapid initially: the number of producers rose by 45 to 76 in 1948, 59 firms entered in 1949, and entry remained high for the next four years, with an additional 44 firms entering in 1950-1953. Subsequently entry dropped sharply, averaging one firm per year through the end of the series in 1989. The number of firms

---

[2] We determined firms' dates of entry into and exit from tv set production during 1947-1989, the period in which the *Factbook* published lists of producers, by examining the lists in each edition and recording the names of all tv set manufacturers and the dates when they were listed as producers. Only the main and most reliable list from the *Factbook* was used, with the exception of several makers of self-assembly tv kits which were included to ensure comparability of the data over time. Mergers and acquisitions were recorded based on information in Datta [1971], Levy [1981], Willard [1982], LaFrance [1985], and Teitelman [1994], and for purposes of Figure 1 the smaller producer was treated as exiting whenever two tv producers came under single ownership. Also in Figure 1, the number of firms is indicated for each volume of the *Factbook*, but entries and exits are summed across quarterly or biannual volumes published in early years of the *Factbook*. For 1947, a count of 31 firms was used based on a reference in the 17 January 1948 issue of *Television Digest and FM Reports* (p. 1) to Supplement 57, which listed TV set manufacturers (the supplement itself could not be obtained despite the publisher's kind efforts).

peaked at 92 in 1951, after which there was a sharp shakeout in the number of producers. By 1958 only 38 firms were left in the industry, and this declined further to 15 in 1974, which is the year before Japanese firms initiated (limited) manufacturing in the U.S. Although Figure 1 indicates that further exit of U.S. producers was largely offset by foreign firms initiating manufacturing in the U.S., the Japanese industry also experienced a shakeout and the combined number of U.S. and Japanese firms continued to decline.

Through 1989 a total of 177 U.S. firms entered the industry, many of which came from the radio industry. According to listings in the marketing journal *Thomas' Register of American Manufacturers*, volumes 1945-1948, 53 of the entrants were radio producers. Among the 16 largest radio producers in 1940 listed in Table 1, 14 entered the industry. These firms quickly came to dominate the television industry. RCA was the early leader. Following its radio policies, it liberally licensed its patents in a pool, provided technical assistance to its licensees, and sold picture tubes liberally to all manufacturers of sets, and after 1958 made all its patents freely available to U.S. firms to settle various antitrust suits. As in radios, this contributed to a decline in RCA's market share and it was eventually displaced by Zenith as the sales leader in both monochrome and color sets. The four-firm U.S. concentration ratio over the period 1948-1980 varied from 41% to 63% in monochrome sets and 57% to 73% in color sets, with RCA and Zenith generally accounting for 40-59% of sales, qualifying the industry as an oligopoly (LaFrance [1985, p. 158]). Other leading firms included GE, Philco, Emerson, Admiral, Motorola, Magnavox, and Sylvania (with subsidiary Colonial), all of which were radio producers.[3]

Similar to radios, the rise in sales of television receivers over time was driven by improvements in quality and reliability and by large reductions in price. The quality of sets was improved greatly through innovations in picture tubes and tuning. After the development of monochrome sets, the most significant tv innovation was the shadow mask tube developed by RCA, which was the basis for the color system approved by the FCC. Process innovation improved the reliability of sets and greatly lowered their price. Over the period 1958-1980 labor productivity in the combined radio and tv industry

[3] Also prominent were Sears Roebuck and Montgomery Ward, which as in radios sold television sets manufactured for them by other firms under their own brand names.

increased by an average of approximately 5% per year, with real tv prices declining at a comparable rate. Many early process innovations were developed by the radio entrants under the direction of their experienced radio engineers.[4] Later process advances were heavily driven by solid-state developments, which made it possible to develop more precise and reliable circuitry using a greater number of circuit elements. Solid state developments also led to a long progression of improvements in manufacturing efficiency as firms steadily streamlined production through automation.

The advent of solid state electronics provided an opening for initially Japanese and later other foreign firms to enter the television industry. Up to 1965 imports of television sets were negligible, but subsequently Japanese firms began exporting to the U.S. all solid-state monochrome sets, a market in which U.S. firms had lost interest. These sets were marketed through chains such as Sears Roebuck and K-Mart that handled their own distribution. It was not long before Japanese exports expanded into color sets, which were generally cheaper and of better quality than U.S. sets. The Japanese firms were consistently ahead of the U.S. firms in the move to solid state components and then integrated circuits, which helped them lead U.S. firms in the development of automated manufacturing methods. As imports mounted in the United States after 1970, U.S. firms that remained in the industry largely moved their operations to Taiwan, Korea, and Mexico to exploit lower labor costs. The Japanese firms also moved to Taiwan and Korea. Later, Korean and Taiwanese firms, some of which had been nurtured by U.S. and Japanese partners, entered the industry, and they and some of the Japanese firms initiated limited manufacturing in the U.S. to counter import restrictions. The move offshore did not stem the exit of U.S. producers, and by 1989 RCA had exited the industry and only three U.S. firms were left. The last of these firms, Zenith, sold out to Goldstar of Korea in 1995.

---

[4] See, for example, Electronics [1947, 1958], DeCola [1948], Tele-Tech [1948a, 1948b, 1948c, 1949, 1950, 1951], Factory Management and Maintenance [1950a, 1950b], Osbahr [1951], Lord [1953], Modern Packaging [1955], and Plesser [1959]. Many revealing articles about the television manufacturing process can found in the journals cited here, particularly *Electronics*.

III. Model of Industry Evolution

In this section, we lay out the basics of the model developed in Klepper [1999] to account for shakeouts and the evolution of an oligopolistic market structure. The model yields implications regarding entry, firm survival, and innovation. These are reviewed and used to develop hypotheses regarding the types of radio producers that entered the tv industry and the effects of their backgrounds on innovation and survival.

The Model

The model depicts the evolution of a new industry. Time is defined in discrete periods t =1,2, ..., where period 1 is the start of the industry. In each period, it is assumed that a new group of potential entrants to the industry arises. Potential entrants can be preexisting firms producing related products. They can also be individuals with the requisite organizational skills and knowledge to start a new firm. It is assumed that potential entrants differ in their capabilities, where the key capability in the model is their ability to manage R&D. This capability is subsumed in a single parameter, denoted as a_i, which scales the productivity of the firm's R&D efforts. Potential entrants are assumed to be able to assess their abilities to manage tv R&D and hence a_i is assumed to be known prior to entry. It is also assumed to be fixed over time.

The productivity of the firm's R&D plays a key role in determining its average cost of production, which is modeled as

$$c_{it} = c_t - a_i g(r_{it}) + \varepsilon_{it},$$

where c_{it} is firm i's average cost in period t, c_t is a cost component common to all firms in period t, r_{it} is firm i's spending on R&D in period t, $\varepsilon_{it} \geq 0$ is a random cost shock to firm i in period t, and as noted above a_i calibrates the productivity of the firm's R&D efforts. In each period, it is assumed that new opportunities for innovation arise. For simplicity, all innovations are assumed to lower average cost. The extent of the reduction in average cost from innovation is determined by the amount of R&D the firm conducts, r_{it}, and the productivity of its R&D, a_i. The function $g(r_{it})$ is assumed to be such that $g'(r_{it}) > 0$ and $g''(r_{it}) < 0$ for all $r_{it} > 0$ to reflect diminishing returns to R&D. All patented innovations are assumed to be licensed and instantly available to all firms and all nonpatented innovations are assumed to be costlessly imitated with a lag, which is assumed to be one period. This is modeled as $c_t = c_{t-1} - l_t - \max_i\{a_i g(r_{it-1})\}$, where l_t is the reduction in average cost associated with patented innovations[5] and $\max_i\{a_i g(r_{it-1})\}$ is the largest cost decrease from nonpatented innovation realized among all firms in period t -1. Last, ε_{it} is a random cost shock that causes the firm's average cost to exceed its minimum possible value in period t. Cost shocks arise from factors such as difficulties in imitating the leading firm's unpatented innovations, unanticipated capital shortages, lax management, etc. It is assumed that cost shocks are independent across periods and thus last for only one period.

In each period, firms are assumed to retain their customers from the prior period, but if they want to expand they must incur a cost of growth of $m(\Delta q_{it})$, where Δq_{it} is the growth in the firm's output and $m'(\Delta q_{it}) \geq 0$ and $m''(\Delta q_{it}) \geq 0$ for all $\Delta q_{it} \geq 0$ to reflect increasing marginal costs of growth. This cost of growth applies to entrants as well as incumbents and thus determines their size at entry.[6] For simplicity, it is assumed that the industry demand curve is fixed over time and that all firms are price takers, so that in each period the price p_t clears the market.

Firms in the industry in period t choose r_{it} and Δq_{it} to maximize Π_{it}, their profits in period t before the realization of the cost shock ε_{it}:

$$\Pi_{it} = [p_t - c_t + a_i g(r_{it})]\,(q_{it-1} + \Delta q_{it}) - r_{it} - m(\Delta q_{it}).$$

Potential entrants in period t enter iff $\Pi_{it}^* \geq 0$ and incumbents in period t-1 remain in the industry iff $\Pi_{it}^* \geq 0$, where Π_{it}^* is the maximum possible profits of firm i in period t. Furthermore, it is assumed that if a firm incurs a sufficiently large cost shock in period t then it also exits. This is modeled by assuming that if $\varepsilon_{it} > p_t - c_t + a_i g(r_{it})$, in which case the firm would incur losses from production in period t, then the firm disbands its R&D operation and permanently exits the industry.

---

[5] Licensed innovations will yield reductions in average cost to licensees if the licensor cannot fully appropriate the value of the innovations through licensing.

[6] Entrants in period t have no output prior to entry and thus enter at size Δq_{it}.

Implications of the Model

Klepper [1999] derives a number of implications of the model. In each period, larger firms invest more in R&D since the total profit from R&D, which equals the reduction in average cost times the firm's output, is scaled by the firm's output. Furthermore, in every period firms expand until the marginal cost of growth equals their profit per unit of output. The firm's profit per unit of output is determined by its investment in R&D and its R&D productivity. Therefore, larger firms and firms with greater R&D productivity have greater profit margins and thus expand faster. Consequently, among firms that entered in the same period, firms with greater R&D productivity conduct more R&D and are always larger and more profitable than firms with lower R&D productivity. Furthermore, among firms with the same R&D productivity, firms that entered earlier start growing earlier and are thus always larger and more profitable than later entrants.

Expansion of incumbents over time and (initially) entry causes the total output of the industry to rise over time and $p_t - c_t$, the average price-cost margin of firms that do no R&D, to decline over time. When $p_t - c_t$ is high initially, the minimum R&D productivity required for entry to be profitable is low and a range of firms in terms of their R&D productivity enter. As $p_t - c_t$ falls over time, the minimum a_i needed for entry to be profitable rises. Eventually entry becomes unprofitable even for firms with the greatest R&D productivity, at which point entry ceases.

The decline in $p_t - c_t$ also causes the profits of incumbents to decline over time. This is partially offset by the rise in firm R&D over time that occurs as firms grow, which lowers firm average costs. In every period, incumbents that experience a sufficiently large cost shock exit. Incumbents also exit when $p_t - c_t$ falls sufficiently that they cannot earn positive profits even if they produce at their minimum possible cost. The latest entrants with the lowest R&D productivity are always the least profitable and thus the most vulnerable to exit. Thus, even after entry ceases, firms exit, with the latest entrants with the lowest R&D productivity expected to exit first. This causes the number of firms to decline steadily over time, resulting in a shakeout. It also causes the earliest entrants with the greatest R&D productivity to take over an increasing share of the industry's output, which contributes to the evolution of an oligopolistic market structure.

Thus, the model predicts that over time firm profit margins decline, entry eventually ceases and a shakeout occurs, and the industry evolves to be an oligopoly. This corresponds to what occurred in the tv industry. As such, the model passes an initial hurdle of being able to account for the key market structure developments in tvs. We now use it to gain further insights into the main issues of the paper, namely how experience in radio production would be expected to influence entry into the tv industry and how heterogeneity among entrants in terms of their radio experience would be expected to influence firm performance.

In the model, entry and firm performance depend on two factors, both of which are assumed to be determined independently of the new industry: the R&D productivity of potential entrants, and the time they gain the ability to enter. Both are influenced by the experiences of potential entrants prior to entering the new industry. Experience in radio production prior to the start of the tv industry is an example of the type of pre-entry experience that would be expected to influence both a potential entrant's tv R&D productivity and also when it became a potential entrant. Radio producers were well positioned early to learn about technological developments in tvs, which were driven by two prominent firms in the radio industry, RCA and Farnsworth. Many had also been in business for some time and thus had well-developed organizations and access to capital to use to mobilize their efforts in tvs. Both factors qualified radio producers as early potential entrants. They also had experience in R&D and distribution that was likely to be useful in managing R&D in tvs. In particular, firms that produced radios for use in the home, primarily for entertainment, had accumulated considerable information about improving and marketing radios that was likely to be useful for tvs, whose principal market was also home entertainment. Indeed, it was noted earlier that (home) radio producers that entered the tv industry used their experienced radio engineers to direct their production-oriented R&D in tvs. It is exactly this kind of research that was not patentable and that in the model distinguishes the firms in terms of their costs (patented innovations were widely licensed and thus available to all firms on similar terms).

It thus seems plausible that firms with experience producing home radios would have a higher R&D productivity in tvs and also qualify earlier as a potential entrant. In the model, firms have no uncertainty about their own prospects or those of the industry, and these two factors completely determine whether and when they enter. Of course, considerable uncertainty prevailed when the tv industry began, but nonetheless it seems reasonable to assume that firms had some awareness of their own prospects and those of the industry. Thus, among firms producing radios prior to the start of the tv industry, it would be expected that their perceived R&D productivity in tvs would vary according to the extent of their experience producing home radios. Since potential entrants with greater perceived R&D productivity would have greater expected profits, this suggests the following hypothesis:

Hypothesis 1: Among firms producing radios prior to the start of the tv industry, the greater their experience producing radios, particularly for home entertainment, then the greater the likelihood of entry into the tv industry.

Furthermore, if firms producing radios prior to the start of the tv industry already had the relevant experience to become tv producers, and hence were among the earliest potential entrants, then those that entered would enter earlier than other entrants. This is stated as hypothesis 2:

Hypothesis 2: Among all firms that entered the tv industry, firms with (home) radio experience prior to the start of the tv industry would enter earlier.

The model provides an indirect way to probe these conjectures further and also to generate hypotheses concerning firm performance. The model predicts that in each period, firms' R&D productivity must exceed a threshold for entry to be profitable and entrants will vary in their R&D productivity. Some, notably entrants without radio experience, might on average be closer to the minimum R&D productivity required for entry to be profitable. Entrants with less experience in (home) radios might have a higher average R&D productivity than nonradio entrants but a lower average R&D productivity than the entrants with the most experience producing (home) radios. Among firms entering at the same time, their R&D productivity determines their profitability and in turn their hazard of exit and market share at any given moment. This suggests the following hypothesis:

Hypothesis 3: Among firms entering at the same time, their initial hazard will be lower and their market share larger the greater their experience producing (home) radios.

Note that to the extent potential entrants correctly anticipate the productivity of their efforts in tvs, hypotheses 1 and 3 imply that the same factors that influence entry among firms producing radios prior to the start of the tv industry should also influence their longevity and market shares.

Hypothesis 3 is framed in terms of the *initial* hazard and market shares of contemporaneous entrants, suggesting that the predicted ordering might not hold as the entrants aged. It holds at young ages because the average R&D productivity of the entrants differs according to their experiences in home radios. Over time, though, the least productive entrants would be more likely to exit, which could cause the average productivity of surviving entrants with different amounts of radio experience to converge. This possibility is illustrated in panel a of Figure 2. Let the upper curve denote the distribution of R&D productivity for entrants with experience producing radios and the lower curve be the distribution for entrants with no radio experience, and let m denote the minimum R&D productivity required for entry to be profitable. The main difference in the two distributions is at the lower end. A relatively high fraction of the entrants without radio experience have an R&D productivity close to or equal to m, whereas very few of the entrants with radio experience has an R&D productivity close to m. In contrast, the distributions overlap at the high end and the maximum R&D productivity for both groups of firms is equal. Over time, as the entrants with the lowest R&D productivity exit first, the average R&D productivity of the two groups will tend to converge, causing the hazards and market shares of the two groups of survivors to converge. Alternatively, suppose, as in panel b of Figure 2, that the maximum R&D productivity of the entrants with radio experience exceeds that of the entrants without radio experience. As the firms with the lowest R&D productivity tend to exit over time, the average R&D productivity would continue to be greater for the surviving radio than nonradio entrants and their hazards and market shares would not converge. This implies the following corollary to hypothesis 3:

Corollary: Among firms entering at the same time, experience producing (home) radios may influence firm hazards and market shares not only initially but also at later stages of evolution of the industry.

The next hypothesis concerns the causal process by which the background of entrants affects their hazard. Holding time of entry constant, the model predicts that firms with greater R&D productivity will do more R&D, which coupled with their greater R&D productivity implies they will account for more innovation than firms with lower R&D productivity. Indeed, this is the basis for why firms with greater experience producing radios are expected to have a lower hazard and greater market share. This implies the following hypothesis:

Hypothesis 4: Among firms that entered at the same time, the amount of innovation they generate per year will be larger the greater their experience producing (home) radios.

If indeed innovation is the key determinant of a firm's hazard, as the model predicts, then introducing measures of innovation and R&D per firm into an econometric hazard model should reduce the influence of firm backgrounds on the hazard. This is stated as hypothesis 5:

Hypothesis 5: If controls are introduced for firm rates of innovation, then the effect of experience producing (home) radios on the hazard should decline.

IV. Empirical Analysis

To probe the hypotheses, we first need to identify the firms producing radios prior to the start of the television industry. Our list of radio producers is based on *Thomas' Register of American Manufacturers*. *Thomas' Register* lists radio producers under the category, "Radio Apparatus: Complete Sets, Outfits, etc." We include in our sample all 265 firms listed in this category in the 1945-1948 volumes of *Thomas' Register*, which list producers in 1944-1947. The listings in the *Television Factbook* indicate that 56 of the 265 firms entered the tv industry.[7]

For each of the 265 firms, we measure its radio experience on three dimensions. The first is based on its size. Larger radio producers were heavily involved in production engineering. Consequently, we expected the larger firms to be more experienced at R&D. For each radio producer, we measured its size according to its capitalization, as reported in the 1948 volume of *Thomas' Register*.[8] *Thomas' Register* classified each radio producer into one of 12 capitalization categories, with firms of unknown capitalization placed in a separate category. The categories in which the radio producers were classified are reported in Table 2. The number of radio producers and the percentage that entered the tv industry in each category is also reported. The top category is open-ended, including all firms with a capitalization of over $1 million. Not surprisingly, perhaps, the entry rate is greatest for firms in this category. Accordingly, one measure we use of the firm's experience is a 1-0 dummy variable equal to 1 for the 58 firms with a capitalization in the top, 4A category. The other 207 firms are treated as the (omitted) reference group.[9]

---

[7] One radio producer entered television manufacture by acquisition, in 1949. Since it was ambiguous whether the firm should be considered a true entrant in its own right, it was excluded from the samples of radio and television producers.

[8] If a firm in our sample was not still listed as a radio producer in the 1948 volume of *Thomas' Register*, we used its capitalization as of the last volume of *Thomas' Register* in which it was listed as a radio producer. We also checked every radio producer that entered the tv industry and found that each had the same capitalization at the time it entered as in the 1948 volume of *Thomas' Register*, so that our measure reflected its size as of its entry into the tv industry,

[9] The capitalization categorization is based on the firm's total assets and thus measures not just its size in radios. For most of the firms, though, radios were their dominant product, so our measure would largely be expected to reflect the size of the firm's radio

The second measure of experience reflects the types of radios each firm produced. *Thomas' Register* has a brief description for the majority of radio firms indicating the type of radios they produced. We divided these descriptions into 11 categories. They are listed in Table 3 along with the number of firms and percentage that entered tvs in each category. The first category, home radios, includes firms with descriptions such as "home," "household receiver," or "combination with phonograph." We interpreted all of these firms as producing radios for the home. The second category includes descriptions indicating receivers, but not designating whether they were for home use. We suspect these firms also largely produced radios for the home, and this is supported by their comparability with home radio producers in the fraction entering tvs. The third category includes firms without any description, suggesting that they typically produced (home) radios which required no further explanation. The other categories are quite different. The largest, radios for aircraft, marine, police, and military, connotes a radio designed primarily for communication rather than home entertainment. This applies as well to the category, communications, 2-way. The miscellaneous category includes firms making custom equipment, special purpose equipment, unassembled sets, and sets for exports, and the commercial category includes firms making coin-operated, hotel, and centralized radios. These all seem quite different from home radios. Accordingly, we constructed two 1-0 dummy variables to reflect the type of radios firms produced. The first, which we label home, equals 1 for the 79 firms in either of the first two categories. The second, which we label unknown, equals 1 for the 65 firms in the third category without any description. The other 121 firms are treated as the (omitted) reference group.

---

investment. To probe this, we examined the classifications of the 16 firms in Table 1 listed as the leading radio producers in 1940. All but two were classified in the top, 4A capitalization category, with the other two in the next category, suggesting a close correspondence between a firm's overall size and its size in radios. We also developed a measure of firm size in radios based on the listing in Table 1, with unlisted firms assigned the average sales of firms outside the listed group. This variable performed similarly to our dummy for capitalization in the top 4A category, suggesting the 4A dummy largely reflected the firm's size in radios.

The last measure of experience equals the number of years the firms produced radios. For each firm we used prior volumes of *Thomas' Register* to ascertain when it was first listed in the category, "Radio Apparatus: Complete Sets, Outfits, etc.," which was started in the 1922 volume. We subtracted this year from the last year it was listed in 1944-1947 to measure its years of experience. This variable took on values ranging from 0 to 25, with a mean and median of 6.6 and 4 respectively.

Entry of the Radio Producers

We begin by testing hypothesese 1 and 2 concerning entry of the radio producers into the tv industry. To test hypothesis 1, we estimated a logit model of the probability of tv entry for the 265 radio producers. The independent variables are the 4A size dummy, the home and unknown radio type dummies, and the years of radio production variable. Maximum likelihood estimates for the model are reported in Table 4. All the coefficient estimates are positive, substantial, and significant at conventional levels, indicating that all three elements of experience increased the probability of radio firms entering the tv industry. The log odds-ratio of entry relative to not entering was 0.111 greater for each additional year of production of radios, 1.348 greater for firms with a 4A capitalization, and 3.041 and 2.313 greater for firms in the home and unknown radio type categories. Among the firms that entered, their years of experience varied from 0 to 25 with a mean of 11.8, 47.4% were in the 4A category, and 89.5% were in the home or unknown radio type category. If the firms in the unknown radio type category are assumed to be home radio producers, the results indicate that nearly all the entrants were home radio producers. Moreover, two of the remaining six, Westinghouse and Sparks-Withington, were well-known home radio producers.[10] Thus, one notable result of the initial analysis is that few, if any, nonhome radio producers entered the tv industry, suggesting that home radio experience was a virtual necessity for a radio producer to be able to compete in the tv industry.

We probed our specification further by first adding a 1-0 dummy for firms with capitalization in the second highest, 3A category. Its coefficient estimate was positive,

[10] Westinghouse had an ambiguous description that prevented it from being classified as a home radio producer.

consistent with the estimate of the 4A dummy, but it was not significant at conventional levels. Second, we divided the years of experience into two variables based on whether firms were in the 4A size category or not. This enabled us to test whether years of experience might just be a proxy for size among the firms in the top, open-ended 4A size category. The estimates for both groups of firms were significantly different from zero and not significantly different from each other, suggesting that the influence of years of experience on entry was not due to size.

Hypothesis 2 conjectures that (home) radio experience conditions not only the decision to enter but also the speed of entry. We tested this by estimating a model for the annual hazard of entry for all 176 entrants into tvs over the period 1946-1989.[11] We used the Cox proportional hazards model, which specifies the hazard of entry of firm i in year t as $h_{it} = f(t)\exp\{\underline{\beta}'\underline{x}_i)$, where h_{it} is the probability of firm entry in year t for firms that have not yet entered by year t, f(t) is a function of time which allows the hazard of entry to change as the industry evolves, $\underline{x}$ is a vector of variables expected to shift the hazard of entry proportionally in each year, and $\underline{\beta}$ is a vector of coefficients. In the Cox model, f(t) is such that the hazard is allowed to take on its best-fitting value each year, and attention focuses on the estimates of the coefficients. We include in the vector $\underline{x}$ three variables: the 4A size dummy, the years of radio production variable, and a dummy variable equal to 1 for entrants that produced radios in the years 1945-1948. We do not attempt to distinguish the radio producers in terms of the types of radios they produced since nearly all of them seem to have produced home radios.[12] Accordingly, we interpret the radio dummy as measuring the effects of experience in producing home radios.

---

[11] The sample period ends in 1989 because the *Television Factbook*, which is our source for data on tv producers, did not publish lists of tv producers after the edition copyrighted in 1989. Its first list was for 1948, and we used information from the 1945-1948 monthly issues of the accompanying trade journal, *Television Digest and FM Reports*, to backdate the listing to 1946. Foreign firms entering U.S. production were excluded.

[12] We experimented by including in our analyses the home dummy, which distinguishes the firms that we were most confident produced home radios from the group without any description (the unknown category) and the other six producers. Its coefficient estimate

Maximum-likelihood estimates of the model computed using Stata are reported in Table 5. All three estimates are positive, indicating that each element of experience contributed to earlier entry, with the radio and size 4A coefficient significant at the .05 level and years of radio production significant at the .10 level (one-tailed). Being a (home) radio producer increased the probability of entry by 73.8% per year, being a size 4A radio producer increased it further by 95.0% per year, and each additional year of radio experience increased the probability by 2.2% per year.[13] These findings support the hypothesis that radio firms were well positioned to enter early, with larger radio producers and secondarily ones that had produced radios longer seemingly having a greater incentive to enter earlier. The estimates of the effects of radio size and years of production are consistent with both factors conditioning the profitability of entry, thereby enhancing incentives for earlier entry.

Survival and Market Share of the Radio Producers

If experience in producing radios affects the probability and timing of entry via its effects on the profitability of entry, then the same experience factors that influenced entry should also affect the performance of tv entrants, as reflected in hypothesis 3 and its corollary. We explore this first by estimating a model for the hazard of exit of tv entrants. We begin again using the Cox proportional hazard model, where the dependent variable is now the hazard of a firm exiting the industry in year t assuming it has survived up to year t. We include the 1-0 radio dummy, the 4A size dummy, and the years producing radios as independent variables. Hypothesis 3 is framed in terms of firms entering at the same time. We saw above that radio firms entered disproportionately early. Thus, if we include all tv entrants in our estimation of the hazard, we risk that

---

was always small relative to its standard error (although generally positively associated with firm performance), suggesting that the radio entrants did not differ much, if at all, in terms of their production of home radios.

[13] To illustrate how these figures are computed, the coefficient estimate of the radio dummy is 0.553, which implies that the hazard of entry for a radio producer is exp(0.553) = 1.738 times the hazard of a nonradio producer, all else equal. Hence radio production increases the hazard of entry by 73.8%.

radio experience could simply proxy for time of entry, which is also expected to condition the hazard. To avoid this complication, we estimate the model using only the 134 firms that entered tvs by 1951.[14] Firms that were acquired by other tv producers were treated as censored exits.[15]

The estimates of the model are reported in the first column of Table 6. All of the coefficient estimates are negative, as predicted, indicating that greater radio experience lowered the hazard of exit. The estimated effects of the radio and 4A dummy are both substantial and significant at conventional levels, with being a radio producer lowering the annual hazard by 59.5% and being a 4A producer lowering it further by 59.6%. The estimate of experience implies a reduction in the hazard of 1.1% per year for each year of experience, although the estimate is small relative to its standard error and is not significant at conventional levels.

In the second column of Table 6 we probe the corollary to hypothesis 3. We drop the insignificant experience variable and generalize the hazard model to allow the radio and size dummy variables to affect the hazard differently in the periods 1948-1954, 1955-1964, and 1965-1989.[16] The first period pertains exclusively to the era of monochrome television, the second corresponds to the period when color tv was introduced but color sales were few, and the third period corresponds to when color tv was successful and international competition became intense. The estimates indicate that the effects of experience were not confined to the early years of the industry but persisted strongly over time. All the coefficient estimates are negative, and the estimates are largest absolutely in the last period, when they are also statistically significant. Prior radio experience decreased the annual hazard by an estimated 69.8%, 36.5%, and 93.9% in the three respective periods, with yet a further estimated reduction of 58.0%, 59.4%, and 68.5% for the 4A radio producers. Based on the reasoning in the theory behind the corollary to

[14] The estimates were similar when all firms were included.

[15] We also estimated the model treating acquisitions as ordinary exits, which had little effect on the estimates.

[16] We also estimated the model including the experience variable, and as expected its coefficient estimate for each period was small and insignificant.

hypothesis 3, the findings suggest that radio experience conferred distinctive competitive advantages that could not be compensated by other types of experience.

Further insight into the role of experience on the hazard over time can be gleaned from Figure 3. A moving average of the annual hazard is computed for three classes of firms: entrants without radio experience (the top curve), less than size 4A radio entrants (the middle curve), and 4A radio entrants.[17] The hazards of all three groups of firms fell around the mid 1950s when the technological frontier temporarily stalled as consumers rejected color tvs, but subsequently the hazards of the nonradio and smaller radio firms increased as the hazards of the larger radio producers stayed roughly constant. Thus, radio experience exerted a substantial effect on the hazard throughout the 40 or so years of the industry that we analyze.

We also test the effect of radio experience on firm market shares by estimating three regressions relating firm tv market shares in 1951-3, 1959-60, and 1970 to the same three experience variables used in the hazard analysis. Data on monochrome market shares for 1951-3 and 1959-60 are from the *Look* Appliance Survey, as reported in Datta [1971, p. 25]. Data for 1970 pertain to color tvs and are from Wooster [1986, pp. 106-107]. The relatively small firms with unreported market shares were assigned average values of the market share not allocated to specific firms. Only the firms surviving in each year were included in the analysis, and the log of market share was used to reduce skewness. Since market share data were available only for a few leading producers, almost all of which were 4A prior radio producers, the radio dummy proved inestimable and the analysis simply compares 4A radio producers versus all other firms combined. The firms with market share data have disparate years of radio production, which enabled us to include the years of radio production variable in each regression. The estimates of

---

[17] For each year t in Figure 3, weighted average numbers of exits and firms were computed using all years with available data within ±10 years. Weights proportional to a Gaussian distribution with mean t and a standard deviation of two years were used, and the weighted number of exits was divided by the weighted number of firms. This approach yields nonparametric estimates of the hazard that avoid major year-to-year fluctuations in raw annual figures.

the regressions are reported in Table 7. The coefficient estimates for the 4A dummy and for years of radio production are positive in each regression, indicating that radio experience increased firm market shares at all three times. The estimates indicate that the main predictor of tv market share is the 4A radio-size dummy. This reflects the fact that with the exception of DuMont Laboratories in 1951-3 and Olympic Radio and Television in 1960, both of which had relatively small market shares, and Motorola in all three periods, all the firms with the largest market shares were 4A radio producers, which conveys the extent to which the U.S. tv industry was dominated by the leading radio producers. Indeed, the estimated coefficient for 4A radio producers is consistently large, and is significant at the .001 and .05 levels (one-tailed) respectively in the first two periods. Only in the final period, when there were only 16 producers, is the 4A dummy insignificant (if only the 4A dummy is included it is marginally significant at the .10 level one-tailed).

Innovation and Survival of the Radio Producers

Hypotheses 4 and 5 probe the mechanism by which radio experience influenced firm performance, featuring the role played by innovation. To test these hypotheses, we need data on the innovations introduced by each firm. Such data are difficult to compile. We found one series on major product innovation through 1979 compiled by Levy [1981] based on interviews with tv executives. Each innovation is dated and attributed to one or more firms. Since we could find no substantial list of process innovations identified with firms and dates, we constructed our own list by using the *Industrial Arts Index* (later *Applied Science and Technology Index*) to look up trade articles related to TV set manufacturing and then examining the articles to find references to new methods in TV set production.[18] Each innovation identified was classified according to its date and

---

[18] Of approximately 210 relevant indexed articles, 198 were obtained and analyzed, yielding a list of 264 process innovations by US firms. Where multiple firms were credited with an innovation, credit was divided evenly among the firms. While large firms may have received more attention from the trade journals, which could impart a bias to the lists, all firms had incentives to report their innovations. Employees in small as well as large firms were given financial incentives by trade journals to write in with

manufacturer(s) involved and was given a 1-7 point subjective estimate of its impact on manufacturing costs. We focus on the years through 1957 when considerable numbers of articles about TV set process innovation were published. These measures of innovation are necessarily crude, but nonetheless should capture some of the key innovative differences across firms.[19]

To test hypothesis 4, we computed separate annual rates of product and process innovation for nonradio producers, less than size 4A radio producers, and 4A radio producers.[20] They are reported in Table 8. Firms with radio production experience had much higher rates of innovation than nonradio producers, and among the radio producers the larger ones had the greatest innovation rates. For product innovation, the mean of producers' annual number of innovations was 0 for the nonradio producers, .011 for the smaller radio producers, and 0.039 for the larger radio producers.[21] For process innovation, the mean rate of innovation was .082, .180, and .670 for the nonradio, smaller radio, and larger radio firms. The patterns are similar when process innovation rates are weighted according to the rankings of the innovations. The statistical significance of these patterns is tested using Wilcoxon's [1945] nonparametric rank-sum test, which tests whether two distributions are different. The test indicates that five of the six inter-group

---

details of process improvements, and manufacturing process articles were a source of considerable prestige for engineers and firms.

[19] More information about the measures of product and process information is in Klepper and Simons [1997].

[20] Given that years of radio production does not lend itself to a comparable treatment and its coefficient estimate was small relative to its standard error in the hazard analyses, we focus just on these three groups.

[21] For both product and process innovations, the annual rate of innovation for each firm was computed by summing its number of innovations and dividing by the number of years it was a TV set producer for which innovations data were available. The mean innovation rate for each group was computed as the average of the annual innovation rate among firms in the group. As in the survival and market share analyses, the data pertain to entrants by 1951, although the findings are similar using all entrants.

differences, all except the larger versus smaller prior radio producers for product innovation, are significant at the .05 level or lower. Thus, radio producers, especially the larger ones, were more innovative than nonradio producers.

To test hypothesis 5, we re-estimated the equation for the hazard of exit including variables measuring firm innovation rates in addition to the radio and size dummies. We combined the product and process innovations data to compute an overall rate of innovation for each firm over the period 1948-1979. We also use an additional measure of innovation based on a classification developed by Willard [1982] for the 19 principal color tv producers that he analyzed. Each firm was assigned a rating of 0 to 3 based on expert opinion regarding its commitment to innovation. We included this rating and a second dummy variable equal to 1 for firms not rated by Willard, which presumably were the least committed to innovation among the producers in the color era. The estimates of this model are reported in Table 9.

We first report estimates of the model with just the radio and 4A dummies in column 1 and then add the innovation variables in column 2.[22] Both innovation variables have a substantial impact on the hazard, with the first significant at the .05 level and the second significant at the .10 level (one-tailed). The innovation rate variable has a standard deviation of 0.85, so a one standard deviation increase in the innovation rate is estimated to yield a 43.0% decrease in the annual hazard. An increase of one point in Willard's innovation ranking is estimated to lower the annual hazard by 59.4%. These effects are large, especially when the effects cumulate over a number of years.

Consistent with hypothesis 5, adding the innovation variables to the statistical model causes the coefficient estimates of the radio and 4A dummies to fall (absolutely). The coefficient estimate of the radio dummy drops 14% from -1.010 to -0.872, and the coefficient estimate of the 4A dummy drops 54% from -0.968 to -0.446. Given the crude nature of the innovation variables, this provides substantial support for hypothesis 5.[23]

---

[22] As before, the years of radio production variable is excluded. Similar conclusions are reached if it is included.

[23] Adding a firm innovation rate variable to the market share regressions of Table 7 has a similar effect. Innovation rates are computed using only years preceding each set of

We report the estimates of one further model in the last column of Table 9. Willard also rated firms' distribution systems on a 0 to 3 point scale. We added this variable to the model to test whether the innovation variables might have been proxying for distributional factors and also to assess the effect of firm distribution networks on the hazard. The coefficient estimates of the innovation variables are hardly affected, suggesting that innovation was an important determinant of the hazard in its own right. Moreover, the coefficient estimate of the distribution variable is positive, suggesting that if anything firms with more extensive distribution networks had higher hazards, though the coefficient estimate on the distribution variable is insignificant.

V. Discussion

Our findings suggest there was great heterogeneity among tv entrants that was related to their performance. About one-third had experience producing radios before tvs. Nearly all of these firms produced radios for home entertainment, and they tended to be larger and to have produced radios longer than radio producers that did not enter the tv industry. Radio producers in general, and the larger and more experienced ones in particular, entered earlier than other firms, and they dominated the industry throughout its history. Nearly all the leading tv producers had been large radio producers, and radio producers, especially the larger ones, consistently had a lower hazard than other entrants throughout the evolution of the industry. Virtually all the major tv product and process innovations were developed by the radio producers, especially the larger ones, and this appears to have been an important element of their success. In summary, the background of firms in terms of their experience in the radio industry had a profound effect on entry

---

market share data, and entrants in 1951 are excluded in the first regression. The 4A size coefficient drops 19%, 53%, and 7% using market share in 1951-3, 1959-60, and 1970 respectively. Thus, the innovation variable explained much of the market share differences that had been attributed to size. Willard's innovation variables, which pertain only to years from 1960 onward, were excluded.

and performance, with the most established home radio producers dominating the tv industry throughout its history.

Our findings provide some insight into the nature of the process governing entry. Among the radio producers, the ones with more experience relevant to tvs were more likely to enter and to enter earlier than firms without radio experience. Mitchell [1989] and Lane [1989] also found that firms with more experience producing related products were more likely to enter new diagnostic imaging markets and the ATM industry respectively, though they were not generally among the earliest entrants. The tv industry was atypical, though, in that it was characterized by far less uncertainty than the average new product by the time it got started following World War II. The technology was commercially feasible even before the War and it was widely available through licensing and sale from RCA, the industry leader, which may help explain the quick entry of the experienced radio producers.[24] Perhaps most interestingly, the same factors governing entry for the radio producers also affected their performance. Producers of (home) radios survived longer and developed more innovations than nonradio entrants, and the larger radio producers and secondarily the ones that had produced radios longer captured the largest market shares, survived the longest, and were the most innovative. This suggests that when making their entry decision, potential entrants were able to anticipate some of the factors that would influence their performance. On the other hand, years of radio production was a considerably stronger predictor of entry than performance, suggesting a la Jovanovic's [1982] model of industry evolution that radio entrants needed to enter to discover fully how their background would affect their capabilities in the tv industry.

Our findings also provide discriminating evidence on the nature of the advantages conferred by prior experience in related products. Lane [1989], Mitchell [1991], and Carroll et al. [1996] found that entrants in ATMs, diagnostic imaging products, and autos with experience in related products outperformed other entrants. Carroll et al. [1996] attributed the advantages of experienced automobile entrants to having established

---

[24] There were also many firms producing radios, and tvs were destined to compete with radios, both factors that Mitchell [1989] found sped up entry into new diagnostic imaging products.

decision making structures and greater access to capital. They conjectured these advantages were greatest when firms were young, and consistent with this they found that certain types of experience had their greatest effect on the hazards of automobile entrants at young ages. In diagnostic imaging products, Mitchell [1989] found that incumbent firms with direct distribution networks were more likely to enter new imaging subfields, presumably because their distribution networks provided them with a competitive advantage over *de novo* entrants. Lane [1989] appealed to learning by doing as the source of the advantage of experienced cash handling, security, and computer firms in the ATM industry. Our findings suggest that these were not the primary ways that experience enhanced the performance of radio producers. In contrast to Carroll et al., producing radios and being a larger radio producer had at least as great an effect on firm hazards at later stages of evolution of the industry, when tv producers were older. Regarding distribution networks, radio producers did sell tvs through their radio distributors, which may have imparted an initial advantage, but tv firm distribution networks had little effect on the hazard during the later evolution of the industry.[25] Last, learning is generally thought to be driven by cumulative experience, typically measured by total cumulative output and years of production, yet the total number of years of radio production was only a weak determinant of performance among the radio entrants. Our findings point to innovation as the source of the advantage of the more experienced firms. A number of the radio entrants used their experienced radio engineers to direct their process-oriented innovation in tvs, and the radio entrants, particularly the larger ones, totally dominated innovation in tvs, which appears to have contributed to their greater longevity.

---

[25] Moreover, Datta [1971] investigated the importance of marketing during the early, monochrome years of the industry and found that firm marketing efforts and advertising had little effect on survival and growth. Television firms could also market through the chain stores, obviating the need for a distribution network. Indeed, this was the way the Japanese firms broke into the U.S. market, which further suggests that distribution networks provided little advantage during the later evolution of the industry.

Klepper's model stresses the importance of both innovation and heterogeneity among entrants in explaining the shakeout and oligopolistic market structure that emerged in tvs. Our findings have largely been consistent with the model. Moreover, a number of other patterns are supportive of the model. At the outset of the industry, firm rates of return on investment were high, enabling a wide range of firms in terms of their capabilities to enter the industry. Over time, though, competition caused firm rates of return to decline sharply, inducing firms to exit. As Wooster [1986, p. 150] notes, the continuing high rate of innovation spurred by semiconductor developments put great pressure on the smaller firms, who could not justify the costs of innovation because they lacked a large enough output over which to spread the costs. Only the largest U.S. tv producers, nearly all of whom had been large radio producers, were able to withstand these pressures, and in the end even they succumbed. All of these patterns resonate with Klepper's model.

There are other explanations for shakeouts, but they accord less closely with our findings. In the theories of Utterback and Suárez [1993] and Jovanovic and MacDonald [1994], a major technological development[26] alters the basis of competition, causing a shakeout by making entry more difficult and forcing out of the industry firms less able to adapt to the new environment. Neither theory predicts that the pre-entry backgrounds of entrants will affect their survival during the shakeout and thus neither theory can address our most salient findings. Indeed, the recent conceptualization of the dominant design theory in Christensen et al. [1998] suggests that pre-entry experience would be disadvantageous because it would wed firms to technologies ultimately rendered obsolete by the emergence of a dominant design. Moreover, both theories suggest a rise in hazard rates with the onset of the shakeout and then a convergence in the hazard rates of different types of firms as the shakeout proceeds (Klepper and Simons [1999]). There was no indication of a rise in hazard rates after the start of the shakeout in tvs (Klepper and Simons [1999]) and the only indication of a convergence in the hazard rates of radio and nonradio firms after the start of the shakeout was short-lived.

---

[26] In Utterback and Suárez the development is the emergence of a dominant design and in Jovanovic and MacDonald it is a major invention developed outside the industry.

Our findings and explanation for the shakeout in tvs also provide a way of understanding the ultimate demise of all the U.S. tv producers. In hindsight, it appears that the U.S. firms were beaten at their own game. The leading Japanese firms were also radio producers. Indeed, they pioneered solid-state radios. They accounted for most of radio imports in the U.S., which by 1964 accounted for 64% of the U.S. market (Wooster [1986, p. 40]). Furthermore, they were nurtured by Japanese industrial policies: tarrifs and restrictions on foreign direct investment limited foreign competition, MITI negotiated favorable technology licenses for all firms collectively, R&D and exports were subsidized, and preferential access to capital was provided (Wooster [1986]). By the 1970s Japan's top five firms were of comparable or greater size than the two largest U.S. firms, Zenith and RCA (Wooster [1986, pp. 151-152]). According to Klepper's model, this provided them with a greater incentive to innovate than all the U.S. producers except RCA and Zenith, and their greater experience with semiconductors provided them with an innovative advantage over RCA and Zenith. This would help explain why in the era of intense international competition the Japanese firms were more willing than the U.S. firms to engage in the costly investments in innovation needed to exploit developments in semiconductors, and why the U.S. firms pursued a more gradual approach to innovation than the Japanese firms involving greater reliance on manual labor in low-wage countries (Wooster [1986, p. 142]).[27]

While pre-entry experience was valuable not only in tvs but also diagnostic imaging products, ATMs, and autos, and no doubt in other industries as well (cf. Klepper [1999]), there have been well publicized instances in which prior experience has seemingly been a handicap in dealing with technical advance (Tushman and Anderson [1986], Henderson and Clark [1990], Christensen and Rosenbloom [1995]). This raises the specter that the importance of pre-entry experience in a new industry may depend on the nature of the industry's technology. A recent dissertation on the evolution of the laser industry (Sleeper [1998]) provides an intriguing counterexample to the television

[27] It cannot explain, though, why earlier the U.S. firms were slow to adopt solid state developments, crystallized by an advertising campaign from 1968 to 1973 conducted by Zenith to promote its hand-wired sets over those produced using solid state components.

industry. The laser industry is over 30 years old and still has not experienced a shakeout. Moreover, experienced and inexperienced firms have had comparable hazards, largely due to the unusually low hazard of *de novo* entrants that were started by employees of incumbent laser producers. This may have to do with the nature of technological change in lasers. For most lasers, the production process is simple and production engineering is not terribly important, which may limit the value of prior experience in related products. Furthermore, many innovations in lasers involve creating new types of lasers that open up new uses and thus appeal to new users of lasers. The returns to such efforts depend only on the number of new customers the firm can attract and do not depend on its pre-innovation output, thus undermining an important advantage that incumbents have in Klepper's model. Thus, even if prior experience provides a firm with an initial advantage, any greater growth it induces will not provide the firm with a continuing advantage, as it would if firm size conditioned the returns from subsequent innovations. Thus, the importance of pre-entry experience both for firm survival and the evolution of a new industry's market structure may depend on the nature of technological change in the new industry, a topic which warrants further study.

VI. Conclusion

Entrants into the tv industry were diverse. A minority had experience producing radios, which set them apart from the rest of the industry. It enabled them to dominate innovation, which in turn contributed to their overall dominance of the tv industry. The diversity of entrants coupled with continual technological change also appears to have shaped the way the market structure of the tv industry evolved.

While the tv industry is just a single case study, it is hardly an isolated one. It raises many fundamental questions. For one, if the experiences of preexisting firms affect their performance in new industries, do the experiences of founders play a similar role for *de novo* firms? Eisenhardt and Schoonhoven's [1990] findings for semiconductors and Sleeper's [1998] for lasers suggests they do, but little is known about these issues. More generally, if preexisting and *de novo* firms draw upon their prior experiences to innovate and compete in new industries, what role do extramarket institutions play in imparting the experiences they draw upon? The success of the Japanese tv producers attests to the potential effect that government policy can have on the capabilities of firms. If indeed extramarket institutions play a key role in shaping firm capabilities, then it behooves us to consider how these institutions can best be designed to play this role.

The way the tv industry evolved also questions the usefulness of models of industrial competition predicated on free entry. Such models presume that all firms are equally capable, which hardly does justice to the diversity that prevailed in the tv industry. Such models also typically embrace the idea of an equilibrium brought about by free entry. This does not resonate well with the prolonged shakeout of producers that occurred in the tv industry.

The evolution of the tv industry has been studied from many angles, but little has been made of the dominance of the industry by experienced radio producers. Our analysis of this dominance raised a host of fundamental questions. Hopefully our findings will go a long way toward providing an answer, at least based on one industry, to the questions raised by Richard Nelson [1991] in the title of his incisive essay, "Why Do Firms Differ, and How Does it Matter?"

References

Carroll, Glenn R.; Bigelow, Lyda S.; Seidel, Marc-David L. and Tsai, Lucia B. "The Fates of De Novo and De Alio Producers in the American Automobile Industry 1885-1981." *Strategic Management Journal*, Summer 1996, *17* (S1), 117-137.

Christensen, Clayton M.; Suárez, Fernando F. and Utterback, James M. "Strategies for Survival in Fast-Changing Industries." *Management Science*, December 1998, *44* (1998), S-207-220.

Christensen, Clayton M. and Richard R. Rosenbloom. "Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network." *Research Policy* 24 (1995), 233-257.

Datta, Yudhishter. *Corporate Strategy and Performance of Firms in the U.S. Television Set Industry*, PhD dissertation (State University of New York at Buffalo, 1971).

DeCola, R. "Monitoring 'Scope for Television Production Lines." *Tele-Tech*, February 1948, 40-41.

Eisenhardt, Kathleen M. and Claudia Bird Schoonhoven. "Organizational Growth: Linking Founding Team, Strategy, Environment, and Growth among U.S. Semiconductor Ventures, 1978-1988." *Administrative Science Quarterly* 35 (1990), 504-529.

Electronics. "Television Production Line." *Electronics*, October 1947, 132-134.

Electronics. "Mechanizing Equipment Assembly." *Electronics*, engineering issue, 24 October 1958, 82-84.

Factory Management and Maintenance. "Laid Out for Low-Cost Handling." *Factory Management and Maintenance* 108 (March 1950a), 70-73.

Factory Management and Maintenance. "These Ideas Pay Off 14 to 1." *Factory Management and Maintenance* 108 (August 1950b), 101-103.

Henderson, Rebecca and Kim Clark. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." *Administrative Science Quarterly* 35 (1990), 9-30.

Jovanovic, Boyan. “Selection and the Evolution of Industry.” *Econometrica* 50 (1982), 649-670.

Jovanovic, Boyan, and Glenn MacDonald. “The Life Cycle of a Competitive Industry.” *Journal of Political Economy* 102 (1994), 322-347.

Klepper, Steven. “Entry, Exit, Growth, and Innovation over the Product Life Cycle.” *American Economic Review* 86 (1996), 562-583.

Klepper, Steven. “Firm Survival and the Evolution of Oligopoly,” unpublished paper (Pittsburgh: Carnegie Mellon University, 1999).

Klepper, Steven, and Kenneth L. Simons. “Technological Extinctions of Industrial Firms: An Enquiry into their Nature and Causes.” *Industrial and Corporate Change* 6 (1997), 379-460.

Klepper, Steven and Kenneth L. Simons. “Industry Shakeouts and Technological Change,” unpublished paper, 1999.

LaFrance, Vincent. *The United States Television Receiver Industry: United States Versus Japan, 1960-1980*, PhD dissertation (Pennsylvania State University, 1985).

Lane, Sarah J. *Entry and Industry Evolution in the ATM Manufacturers’ Market*, PhD dissertation (Stanford University, 1989).

Levy, Jonathan. *Diffusion of Technology Patterns of International Trade: The Case of Television Receivers*, PhD disseration (Yale University, 1981).

Lord, K.M. “Mechanized Dip Soldering.” *Electronics* (June 1953), 130-137.

MacLaurin, W. Rupert. *Invention & Innovation in the Radio Industry* (New York: MacMillan Company, 1949).

Mitchell, William. “Whether and When? Probability and Timing of Incumbents’ Entry into Emerging Industrial Subfields.” *Administrative Sciences Quarterly* 34 (1989), 208-230.

Mitchell, William. “Dual Clocks: Entry Order Influences on Incumbent and Newcomer Market Share and Survival When Specialized Assets Retain Their Value.” *Strategic Management Journal* 12 (1991), 85-100.

Modern Packaging. “Parts by the Reel.” *Modern Packaging*, August 1955, 100-101, 186-188.

Nelson, Richard R. "Why Do Firms Differ, and How Does It Matter?," *Strategic Management Journal* 12 (1991), 61-74.

Osbahr, Bernard F. "Production Aids in Television Receiver Manufacture." *Tele-Tech*, April 1951, 42-43, 83.

Plesser, E.W. "Simple Machines, Too, Build TV Sets." *American Machinist* (19 October 1959), 160-163.

Sleeper, Sally D. *The Role of Firm Capabilities in the Evolution of the Laser Industry: The Making of a High-Tech Market*, PhD dissertation (Carnegie Mellon University, 1998).

Teitelman, Robert. *Profits of Science* (New York: Basic Books, 1994).

Tele-Tech. "Conveyer and Test Systems Speed TV Set Assembly." *Tele-Tech*, March 1948a, 36-38.

Tele-Tech. "TV Receiver and Parts Assembly Techniques." *Tele-Tech*, October 1948b, 32-35.

Tele-Tech. "Television Engineering and Manufacturing at Philco." *Tele-Tech*, November 1948c, 61-94.

Tele-Tech. "DuMont Opens Largest TV Assembly Plant." *Tele-Tech*, October 1949, 24-25.

Tele-Tech. "Test Equipment in TV Receiver Manufacture (First of a Series)." *Tele-Tech*, September 1950, 35-35, 77-79.

Tele-Tech. "Test Equipment in TV Receiver Manufacture (Second of a Series)." *Tele-Tech*, April 1951, 30-32, 76-81.

Tushman, Michael L. and Philip Anderson. "Technological Discontinuities and Organizational Environments." *Administrative Science Quarterly* 31 (1986), 439-465.

Utterback, James, and Fernando Suárez. "Innovation, Competition, and Industry Structure." *Research Policy* 22 (1993), 1-21.

Wilcoxon, F. "Individual Comparisons by Ranking Methods." *Biometrics* 1 (1945), 80-83.

Willard, Gary E. *A Comparison of Survivors and Non-Survivors under Conditions of Large-Scale Withdrawal in the U.S. Color Television Set Industry*, PhD dissertation (Purdue University, 1982).

Wooster, James H. *Industrial Policy and International Competitiveness: A Case Study of U.S.-Japanese Competition in the Television Receiver Manufacturing Industry*, PhD dissertation (University of Massachusetts, 1986).

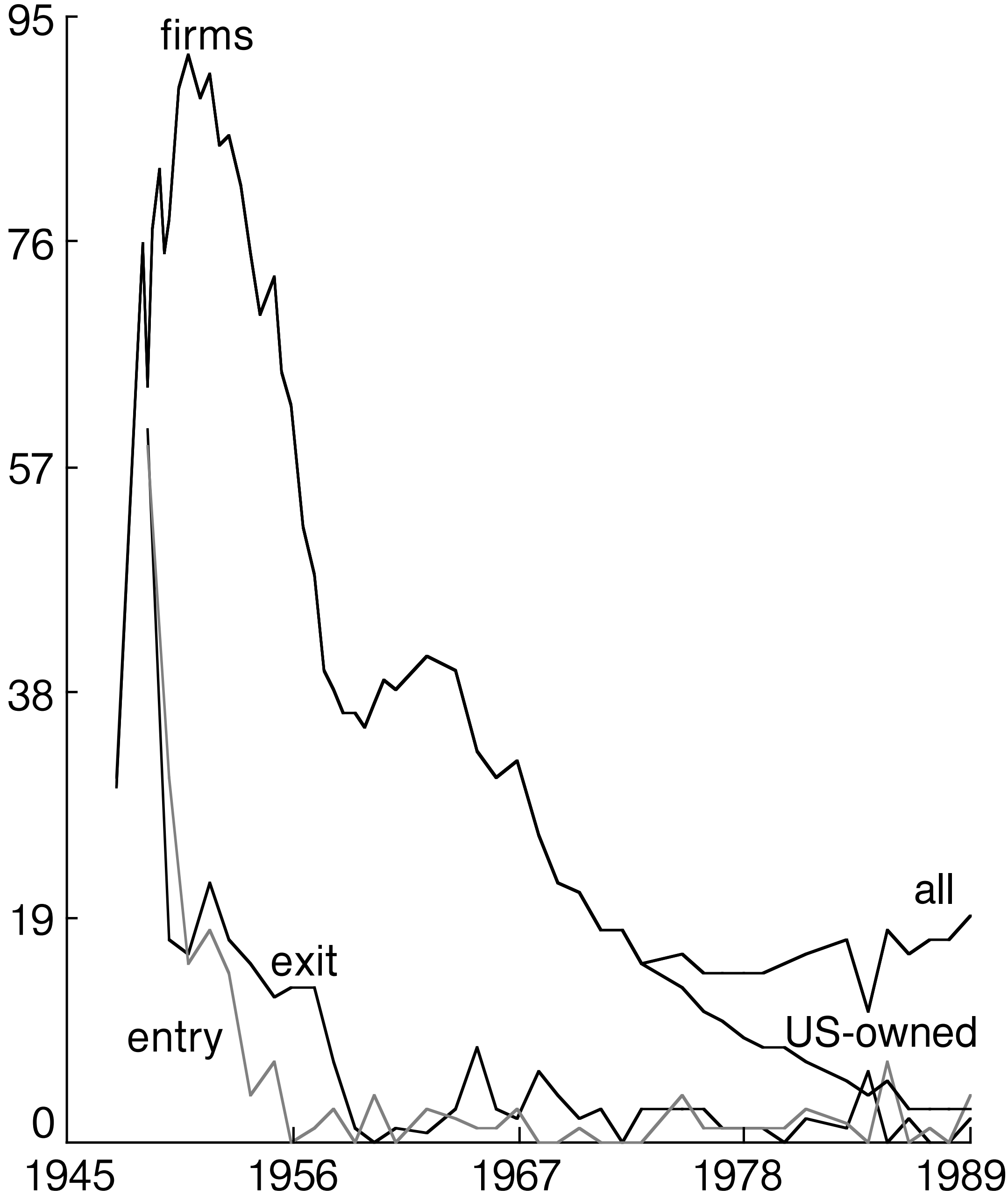
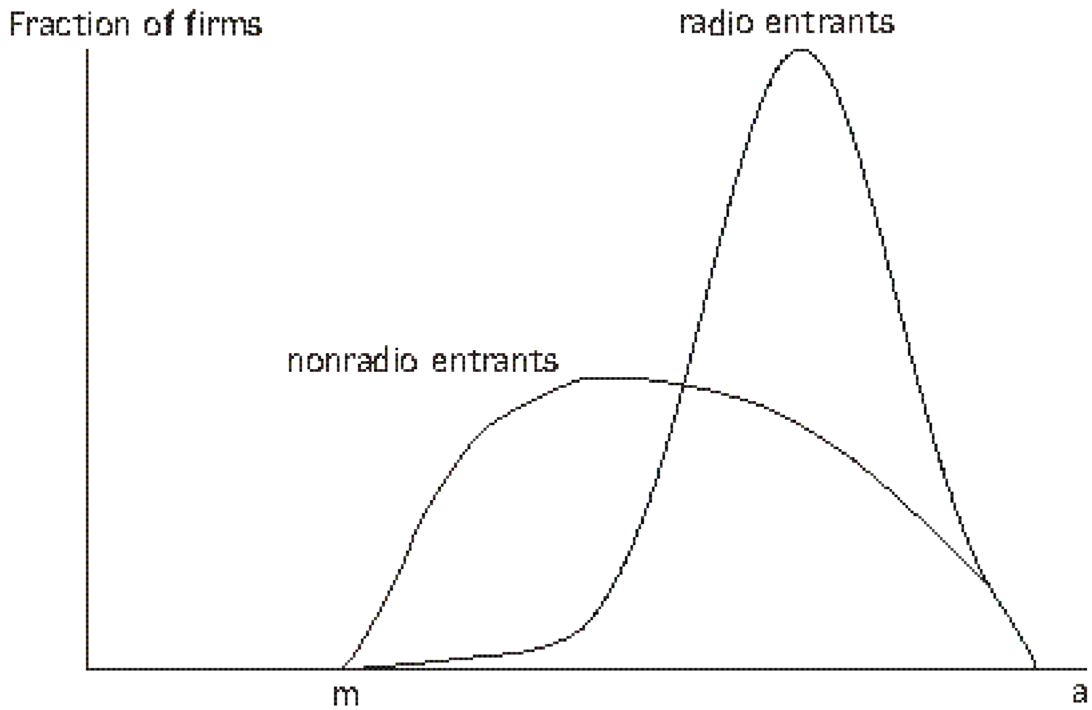
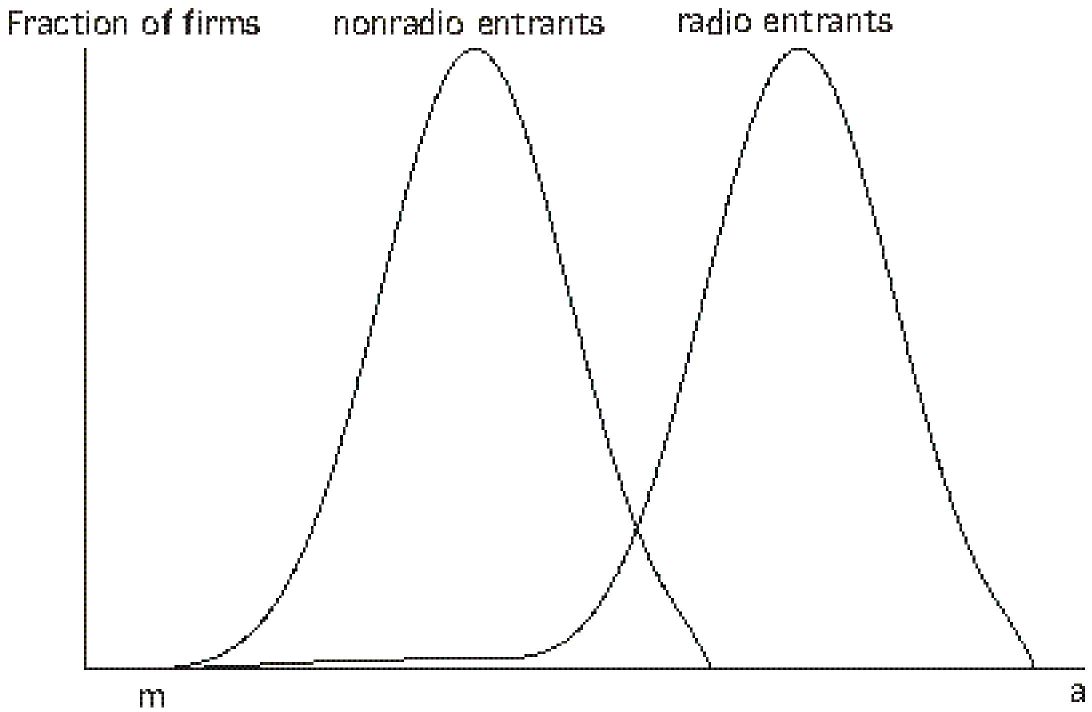


Figure 1 – Number of Firms, Entry, and Exit in TVs



A. Identical maximum capability for radio and nonradio entrants.



B. Higher maximum capability for radio versus nonradio entrants.

Figure 2 – Alternative Distributions of Capability for Radio and Nonradio Entrants

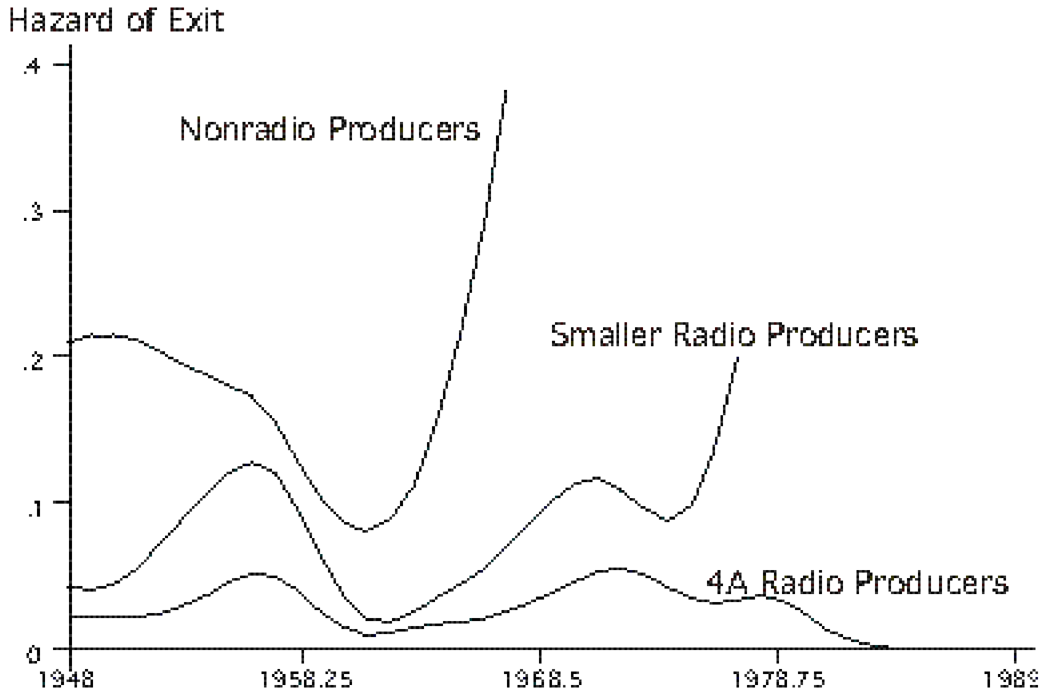


Figure 3 – Moving Average Hazard of Exit among TV Producers

Table 1 – Sixteen Large Radio Producers in 1940

Firm	Sales in 1940 (thousands)
Radio Corp. of America	1700
Philco Corp.	1675
Zenith Radio & Phonograph Corp.	1050
Emerson Radio & Phonograph Corp.	1050
Galvin Mfg. Corp. (Motorola)	950
Colonial Radio Corp.	650
Belmont Radio Corp.	550
Noblitt Sparks Industries Inc.	400
Crosley Corp.	350
General Electric Co.	350
Simplex Radio Corp.	250
Stewart-Warner Corp.	250
Electrical Research Laboratories	250
Wells-Gardner Co.	200
Farnsworth Television & Radio Corp.	100
Sparks-Withington Co.	100
All other producers	1584

Source: MacLaurin [1949, p. 146].

Table 2 – Number of Radio Producers and TV Entry Rate for Alternative Size Categories

Capitalization Category (*Thomas'* Code)	Number of Radio Producers	% Entering TV Production
Over $1 million (4A)	58	44.8
$500,000 - $1 million (3A)	23	21.7
$300,000 - $500,000 (2A)	12	25.0
$100,000 - $300,000 (A)	57	15.8
$50,000 - $100,000 (B)	24	8.3
$25,000 - $50,000 (C)	10	0.0
$10,000 - $25,000 (D)	10	10.0
$5,000 - $10,000 (E)	3	0.0
$2,500 - $5,000 (F)	1	0.0
Unknown (X)	67	14.9
All radio producers	265	21.1

Table 3 – Number of Radio Producers and TV Entry Rate for Alternative Product Categories

Product Type Category	Number of Radio Producers	% Entering TV Production
home radios	63	49.2
receivers	16	31.3
no special type indicated	65	21.5
portable, compact, miniature	7	14.3
automobile	1	0.0
communications, 2-way	13	15.4
“transmitters & receivers”	6	0.0
aircraft, marine, police, military	46	4.3
commercial	10	0.0
experimental radios or R&D	5	0.0
miscellaneous	33	3.0
All radio producers	265	21.1

Table 4 – Logit Model for TV Set Entry

Variable	Coefficient Estimate (Standard Error)	
Constant	-4.619	(0.607)
Capitalization over $1 million	1.348***	(0.420)
Home radio producer	3.041***	(0.568)
Unknown-type producer	2.313***	(0.612)
Years of radio experience	0.111***	(0.025)
Log likelihood	-91.739	
N	265	

† p < .10, * p < .05, ** p < .01, *** p < .001 (one-tailed)

Table 5 – Cox Proportional Hazard Model for TV Set Entry

Variable	Coefficient Estimate (Standard Error)	
Radio producer	0.553*	(0.267)
Capitalization over $1 million	0.668*	(0.292)
Years of radio experience	0.022†	(0.017)
Log Partial Likelihood	-744.196	
N	176	

† p < .10, * p < .05, ** p < .01, *** p < .001 (one-tailed)

Table 6 – Cox Proportional Hazard Model for TV Set Exit
(Standard Errors in Parentheses)

Variable	1		2	
Radio producer	-0.904**	(0.327)		
in 1948-1954			-1.196***	(0.359)
in 1955-1964			-0.455	(0.418)
in 1965-1989			-2.797**	(1.126)
Capitalization over $1 million	-0.906**	(0.374)		
in 1948-1954			-0.867†	(0.601)
in 1955-1964			-0.900†	(0.558)
in 1965-1989			-1.156*	(0.680)
Years of radio experience	-0.011	(0.022)		
Log Partial Likelihood	-449.853		-446.589	
N	134		134	

† p < .10, * p < .05, ** p < .01, *** p < .001 (one-tailed)

Table 7 – OLS Models for Log of TV Set Market Share at Consecutive Times

(Standard Errors in Parentheses)

	Dependent Variable: Market Share in		
Variable	1951-3	1959-60	1970
Constant	-1.352	-0.746	-0.485
	(0.136)	(0.296)	(0.844)
Capitalization over $1 million	0.943***	1.011*	0.959
	(0.295)	(0.489)	(0.901)
Years of radio experience	0.016	0.035†	0.023
	(0.015)	(0.026)	(0.051)
R^2	0.235	0.329	0.131
N	83	32	16

† p < .10, * p < .05, ** p < .01, *** p < .001 (one-tailed)

Table 8 – Innovations per Firm per Year
by Prior Radio Production and Radio Size

Type of TV set producers	Product innovation	Process innovation
Non-radio (N=81)	0	.082
Radio small (N=28)	.011	.180
Radio large (N=25)	.039	.670

Statistical Significance p-values (Wilcoxon rank-sum test)

Types	Product innovation	Process innovation
Radio large vs. Non-radio	.000	.000
Radio small vs. Non-radio	.016	.001
Radio large vs. Radio small	.155	.038

Note: Product innovation from 1948-79. Process innovation from 1948-57.

Table 9 – Effects of Prior Radio Experience, Innovation, and Distribution on TV Producers' Exit

Variable	1		2		3	
Radio producer	-1.010***	(0.251)	-0.872***	(0.255)	-0.843***	(0.256)
Capitalization over $1M	-0.968**	(0.353)	-0.446	(0.360)	-0.516†	(0.378)
Innovation rate			-0.666*	(0.308)	-0.704*	(0.319)
Willard innovation			-0.901†	(0.590)	-1.164*	(0.700)
Willard distribution					0.441	(0.631)
Willard no data			1.836*	(0.983)	2.181*	(1.101)
Log Partial Likelihood	-449.975		-438.463		-438.210	
N	134		134		134	

† p < .10, * p < .05, ** p < .01, *** p < .001 (one-tailed)